REPORT RESUMES

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STRENGTH AND OTHER CHARACTERISTICS OF BOOK PAPERS 1800-1899.
PERMANENCE/DURABILITY OF THE BOOK--V.
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OBJECTIVES OF THE STUDY WERE TO--(1) ASCERTAIN THE PRESENT STRENGTH OF BOOK PAPERS TYPICAL OF THOSE MANUFACTURED DURING THE 19TH CENTRUY AND NOW PART OF AMERICAN RESEARCH LIBRARY COLLECTIONS, (2) IDENTIFY CAUSES OF DETERIORATION, (3) PROPOSE A SIMPLE METHOD FOR IDENTIFYING VOLUMES NEEDING STABILIZATION, AND (4) RECOMMEND METHODS OF STABILIZATION. THE EXAMINATION OF 500 NON-FICTION BOOKS PUBLISHED FROM 1800-1899 REVEALED THAT THE MAJOR CAUSE OF THE DETERIORATION OF BOOK PAPER AFTER MID-19TH CENTURY IS THE ACIDITY OF ALUM-ROSIN SIZE, WHICH WAS USED INCREASINGLY TO SIZE BOTH WOOD PULP AND RAG FIBER PAPERS. ALTHOUGH WOOD PULP WAS REPLACING RAG FIBER AT THIS TIME AND IS POPULARLY THOUGHT TO BE THE MAIN REASON FOR LOSS OF BOOK PAPER STRENGTH, THE STUDY SHOWED THAT ALL-RAG PAPERS SUFFERED A SIMILAR DROP IN QUALITY. THE CHLOROPHENOL-RED SPOT TEST WAS FOUND TO BE RELIABLE FOR INDENTIFYING MOST OF THE BOOK PAPERS NEEDING STABILIZATION. THE STUDY ALSO FOUND THAT PRINTER'S INK DID NO VISIBLE DAMAGE TO THE PAPERS TESTED, ALTHOUGH IT CAUSED A LOSS OF 30 PERCENT IN FOLDING STRENGTH. METHODS RECOMMENDED FOR DELAYING OR PREVENTING DETERIORATION OF 19TH CENTURY BOOK PAPERS INVOLVE DE-ACIDIFICATION AND STORAGE AT LOWERED TEMPERATURES. APPENDED IS A LIST OF BOOKS TESTED, A TABULAR PRESENTATION OF TEST DATA, AND A BIBLIOGRAPHY OF 43 ITEMS. THIS STUDY WAS CONDUCTED UNDER A GRANT FROM THE COUNCIL ON LIBRARY RESOURCES AND IS ALSO AVAILABLE FROM THE W.J. BARROW RESEARCH LABORATORY, INC., 428 N. BLVD. P.O. BOX 7311, RICHMOND, VIRGINIA 23221, FREE OF CHARGE. (JB)

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Strength and Other Characteristics of Book Papers 1800-1899

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Strength and Other Characteristics of Book Papers 1800-1899

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I. Introduction

All who, whether as readers of books, book-collectors or librarians, have had much to do with the publications of the 19th century are very conscious of the seriously weakened and deteriorated condition of many of these books. It is usual to place the blame for this situation on the extensive substitution of wood or other cheap fibers for rag in the manufacture of book papers after mid-century, and to point to the almost exclusive use of rag to explain the better survival of the papers of the earlier decades.[1]*

Upon investigation, however, this is found to be an over-simplification of a complex situation.

Increasing demands throughout the 19th century for more and cheaper papers stimulated new developments in production. The new papers were weaker initially and deteriorated faster. Both factors contributed to a short lifespan. Although John Murray in the *Gentleman's Magazine* in 1823[2] and later in a pamphlet in 1829,[3] and T. C. Hansard in *Typographia,* 1825,[4] sounded warnings of this decline in paper quality, book paper manufacturers did not heed—greatly or permanently—either man's advice.

By the end of the 19th century librarians and archivists faced a serious paper deterioration problem.[5] A full-dress investigation was conducted by the Committee on the Deterioration of Paper appointed in June 1897 by the Society of Arts (London). In an influential report published in May 1898 the Committee reported that "the danger had been overestimated." As to the causes of those cases of actual disintegration of paper which had been called to its attention, the Committee found these to result from "chemical changes of fibers" and the "effects of illuminating gas upon the atmosphere of the rooms in which the books had been stored."[6]

The emphasis thus given to the "polluted industrial atmosphere" theory of paper deterioration has persisted right down to the present time, and for most of the period has succeeded in distracting attention from the more important causes of deterioration.

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*References are to the publications listed in the Bibliography.

In 1957-8 the author of the present report conducted an investigation under the auspices of the Virginia State Library to ascertain the causes and to explore the possible remedies for the deterioration of book stock in American libraries. This investigation, which was limited to book papers of the 20th century, took for its subject a sample consisting of 500 books printed in the United States, 1900-1949, 100 for each decade. The results of the study were published[7] and laid the basis for further experimentation which resulted in the development of permanent/durable book paper marketable in the medium price range for book papers.[7]

Subsequent work in this laboratory relating to the stabilization of deteriorating book papers has contributed to plans for a national preservation program drawn up by the Association of Research Libraries and the Library of Congress.[8] In the course of this work more precise information than was available has been needed as to the actual condition of book papers manufactured prior to 1900, and, if possible, as to the factors responsible for their condition. The investigation reported in the following pages, conducted in 1963-1965,* represents the first attempt to assemble such information with the use of the techniques developed in the 1957-8 study.

It is hoped that the present report, by contributing to improved understanding of what actually happened to paper in one of its most important centuries, may assist to a better use of this product on which man and his civilization has become so dependent.

WILLIAM J. BARROW

Richmond, Virginia
August 1967

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* These studies, as well as those previously mentioned, were supported by a grant from the Council on Library Resources, Inc. which was established with funds from The Ford Foundation.

II. Objectives and Tests

Purposes of the Study

The purposes of the study here reported were (a) to ascertain the present strength of book papers typical of those manufactured during the 19th century and currently represented in the collections of American research libraries; (b) to identify the principal causes of deterioration; (c) to propose a simple method for identifying volumes needing stabilization; and (d) to recommend appropriate methods of stabilization.

Test Specimens

Only regular book papers used in letterpress printing were used in the study. A total of 500 books, 50 for each decade from 1800 to 1899, were assembled by Dr. Ray O. Hummel, Assistant Virginia State Librarian and Consultant to this laboratory. These books were in general little-used non-fiction works showing no visible evidence of heavy use, abuse, mold, or storage under unusual conditions of temperature or moisture. Although most of the books were obtained from sources in or near Virginia, this fact could not of course assure that they had all been stored in this particular climate since they were printed, and indeed, a few were purchased from dealers in England.

A list of the books with their dates and places of publication appears as Appendix A. For the books of the first four decades the place of origin is also indicated by a letter affixed to the specimen number in Table 1. Approximately 300 publishers are represented by the selection and 9.8% of the total were published outside the United States. While strict random sampling of surviving 19th century book papers was of course impossible, the selection is believed to represent a good cross-section of 19th century books likely to be found in American research libraries.

The leaves selected for testing were taken at random from various parts of the books and were conditioned prior to testing by suspension overnight in a testing room where modern instruments indicated the atmosphere was held to the conditions of 73° F. ± 0.25 and R. H. (Relative Humidity) 50% ± 0.5. To avoid the effects of light, dust and polluted atmosphere on the exterior margins of the pages of books, test specimens were taken at least a quarter of an inch from outer edges.

Tests—Because a detailed chemical analysis was beyond the scope of this study, the tests used were limited to those required to produce relevant information. Of the many tests to which paper can be subjected, the most useful for measuring present and for predicting future usefulness in books (as contrasted with use in paper bags, for example) are those which were identified as useful for this purpose during the earlier study of 20th century papers,[9] namely, tests for folding endurance, tear resistance and acidity. To these were added certain other tests described below.

Unless otherwise noted, all tests were made on the uninked areas of the leaves and in accordance with the standards of the Technical Association of the Pulp and Paper Industry (TAPPI).[10]

Folding Endurance—Thirty strips from each book were tested under 1/2 kilogram tension in the Massachusetts Institute of Technology Folding Endurance Tester to simulate the type of stresses set up when a leaf is flexed to and fro as in turning a page. Twenty strips were tested Cross Printing (C. P., i. e. with the fold at right angles to the lines of print). Of these, 10 strips were tested with the fold in the inked area and 10 with the fold in the uninked area. The other 10 strips were tested With Printing (W. P., i. e., with the fold in the direction of the lines of print and in the uninked areas only). The results in each group were averaged.

Tear Resistance—Eight strips per book were tested in the Elmendorf Tear Resistance Tester for each direction C.P. and W.P. to simulate resistance to pull when a leaf is turned, and the results averaged.

Acidity (*pH*)—Two specimens from each book, one from an inked and one from an uninked area, were tested by the cold extraction method using a Beckman meter. [10, 11] The pH scale is a logarithmic scale in which each unit reflects a ten-fold change in acidity/alkalinity, while each 0.3 unit reflects a doubling or halving, as follows:

Acidity	*pH*	*Alkalinity*
	10	1000
	9.6	400
	9.3	200
	9	100
	8	10
1	7	1
10	6	
25	5.6	
50	5.3	
100	5	
1000	4	

Acidity (Spot Test)—In order to ascertain the practicality of a spot test for acidity in 19th century book papers, the results of such a test are reported in Table 1 where they may be compared with the data obtained by the cold extraction method described above. In case of differences the tests were repeated using the same sheet of paper for both tests, since more than one batch of paper might have been used in the book.

The solution used for the spot test consisted of 0.42 grams of chlorophenol-red in a liter of water. A very small drop was placed on an unimportant area of a leaf or on a sliver cut from the foot of a page. If the spot remained purple it indicated a pH 6.0 or above, but if it turned yellow it indicated a lower pH value.[12]

Chlorides and Sulfates [13, 14]—Chloride content was determined by titrating an aqueous extract from a one-gram sample of paper with silver nitrate in the presence of potassium chromate. The endpoint was indicated by the formation of red silver chromate.

Sulfate content was determined on one-gram paper samples which were extracted with water. Barium chloride was added to the extract to precipitate sulfate as barium sulfate. Timing, temperature and agitation were carefully controlled. Light transmittance (at 420 millimicrons) of the suspension was compared with a standard curve obtained by plotting transmittance values of solutions of known sulfate concentration which had been treated in the same way.

Rosin—The Raspail spot test for rosin was used to determine the presence of alum-rosin sizing.

This test is run by putting a drop of sugar water solution on paper with an eyedropper. With filter paper spread the spot and wipe off excess liquid. Onto the spot of sugar water, spread a circle of sulfuric acid (96.6%—caution) with an eyedropper. This must be done carefully, and not touched with the hand or clothing because there is danger of burning skin or eating holes through clothing. If rosin is present, the spot will turn a decided pink color; if there is no rosin, the spot will remain colorless or turn a brownish color.

Fiber Analysis—Using a regular paper technologist's microscope, fibers were classified as rag, straw, groundwood and chemical wood. The latter were further classified as either hard or softwood. Fibers were further classified according to length.

Cotton vs. Flax Fibers—After the fiber analysis was completed as described above, an attempt was made to trace the replacement of flax by cotton as the principal constituent of paper following the invention of the cotton gin in 1793, with a view to ascertaining whether this replacement had any significant effect on the strength or durability of paper.

Efforts were made to find a method for differentiating cotton from linen fibers. Leading paper laboratories were consulted but could give only procedures for differentiating fibers before processing, not after they had been made into paper. However, through the courtesy of the Philip Morris Research Laboratory, Mrs. Virginia C. Johnson, microscopist, became a special consultant to this laboratory and with her aid a successful procedure has been developed.[15]

It was discovered that it was easier to distinguish the structural organic (morphological) characteristics of a fiber by using polarized light, because fibers suffer mechanical and chemical degradation while being processed for papermaking.[16] Polarizing disks were added in the eyepiece and in the accessory slot ring beneath the substage iris of a regular paper technologist's microscope. The fiber slides were prepared in three stages: 1) an uninked section of a book page was torn out, 2) this section was beaten in a Waring blender until the paper disintegrated, and 3) portions of these fibers (after reaching a pulpy consistency) were put on the slide and drops of methyl salicylate were added as a mounting medium.

Cotton fibers are oval in section while flax fibers are polygonal to round.[16, 17] Lengthwise, cotton appears twisted with no nodes, while flax has transverse X-like nodes at intervals, giving the fiber the appearance of a bamboo stalk. Cotton fibers fibrillate readily along the whole length, while flax fibrillates more slowly and at the ends only. Cotton fibers are more translucent than flax as well as more birefringent under polarized light.

Groundwood—The presence of groundwood in paper is indicated if a drop of phloroglucinol solution, placed upon the sheet in question, turns from yellow to reddish-brown.

Basis Weight and "Easily Torn Category"—The basis weight of a paper is the weight in pounds avoirdupois of 500 sheets, 25 x 38 inches in size. (The basis weight multiplied by 1.48 gives the weight in grams per square meter.) In the report of a previous study of this laboratory it was shown that, for optimum usefulness of a book paper, its tear resistance should be proportional to its basis weight. For example, an 80-pound paper reaches the "easily torn category" when its tear resistance drops to 34 grams, while a 30-pound paper does not reach this category until it has reached 11 grams.[18] Accordingly, in order to relate the tear resistance data of the papers of the present study to their usability, the basis weight was calculated by weighing 4 samples 2 1/2" x 2 1/2" and multiplying by 41.9 for a ream 25" x 38" and is reported in Table 1 together with the tear resistance value at which paper of this weight reaches the "easily torn category." The tear values of the papers in the "easily torn category" are underscored.

III. Historical Developments

The spread of literacy and the increase of communications during the 18th century presented the opening years of the 19th century with a greater demand for paper than ever before.[19, 20] Technological developments which helped satisfy immediate needs for more paper originated in the late 1700's. "Necessity, the mother of invention" accounts for many of the developments in papermaking during the 1800's. All in all, however, there were more new developments in papermaking in the 19th century than had occurred since paper first reached the Occident in the 12th century.

Among the major developments affecting papermaking in the 19th century (with consequences for the permanence/durability of the product) were a) the discovery of chlorine, 1774; b) the invention of the cotton gin, 1793; c) the demonstration that straw and wood could be used to make paper, 1800; d) the introduction of the Fourdrinier (continuous) papermaking machine, ca. 1803; e) the invention of alum-rosin size, 1807; f) the use of fillers from ca. 1810; g) the production of paper from groundwood, 1840-1860; h) the production of paper from chemical wood fibers (and other substitutes for rag), 1850-1884; i) invention of the Jordan, 1860.[19, 20]

Chlorine Bleach—In the second half of the 18th century cloth was bleached by a process which consisted of alternate soakings in alkaline and mildly acid solutions, with intervals of exposure to sunlight and air. The alkaline solutions contained lime, wood ashes, etc.; the acid solutions were at first sour milk, but it was found that dilute sulphuric acid greatly speeded the operation.[21] Although this process was extensively used for bleaching new cloth, in which it may have left some insoluble sulfates which later found their way into paper, it does not appear to have been used to whiten dyed rags or rags discolored from use. But chlorine, discovered in 1774 by Karl Wilhelm Scheele, had the capability of doing this. The effect of this discovery was not long in reaching the paper industry. The bleaching of rags and half stuff (paper pulp) with "muriate of lime" (calcium hypochlorite) was described in Campbell's (British) patent in 1792, and thereafter the use of chlorine bleach became general, even including the bleaching of finished paper with chlorine gas.[3, 22]

An immediate result was to permit the use of discolored and weakened rag which had not previously been usable. But in addition, because the bleach was, as John Murray described it, "generally clumsily or incautiously or unwarily employed," even strong fibers were sometimes weakened. As a horrible example Murray described a Bible, printed only 13 years earlier (in 1816) by the Oxford University Press and never used, but already "CRUMBLING LITERALLY TO DUST."[3] (The capital letters are Murray's).

Although papermakers learned from such instances to curb the worst excesses of bleaching, the fact remains that bleaching has ever since been one of the factors that must be reckoned with when considering the behavior of paper. Chlorine in particular is a strong oxidizing agent, capable of combining with moisture to form hypochlorous acid. It is capable of damaging cellulose unless used under carefully controlled conditions, when its effect can be considered minor.[3, 23, 24, 25]

Rag Fibers—Until 1850 printing and writing papers in the Occident were composed exclusively of fiber obtained from rag clippings and used rags.[26, 27] At the beginning of the century flax (linen) was the principal rag fiber, but the invention of the cotton gin in 1793 stimulated a decade-by-decade doubling of cotton production, while the production of flax did not increase proportionally.[28] It was consequently to be expected that cotton would eventually supersede flax as the principal rag fiber. However, because cotton and flax were mixed in the manufacture of some fabrics (such as jeans),[27, 29] and because old cotton and linen rags were collected indiscriminately by paper manufacturers from the populace of a locality, the proportion of cotton to flax in paper might vary greatly over a long period.

Cotton is considered the purest naturally-occurring cellulose fiber. For that reason it requires less harsh processing than flax to reach the desired whiteness. As a result it may have produced the stronger fiber in the early decades of the 19th century, as was believed by some at that time.[30] However, because of the many variables in papermaking in the all-rag paper period

(1800-1849) it is difficult to determine whether and to what degree cotton fiber affected the strength and stability of paper.

Straw and Wood Fibers—A number of experiments in making paper from sources of cellulose fibers other than rag were conducted during the 18th century. But in 1800 Mathias Koops effectively demonstrated the feasibility of using straw and wood for this purpose by publishing in London a book of which the body was on paper made from straw and the appendix on paper from wood.[31] However, the increased production of cotton at the time deferred the need for Koops' invention for almost half a century.

The Papermaking Machine—The Fourdrinier continuous papermaking machine was introduced in the first decade of the 19th century. By 1850 it was in general use.[19, 32] Murray criticized it in 1829 because its woven wire mold lent itself to the use of short fibers, resulting in the production of paper which, though smoother than the paper obtainable with the laid mold, was much weaker.[3] Despite his criticism, production soared. Because the success of the machine depended upon its economy, one element in which was its ability to make use of previously unusable short fibers, this result was to be expected.

Another way in which the papermaking machine is believed by some to have affected the strength and longevity of paper is by introducing differences in strength in the two dimensions of the sheet. When made by hand, the papermaker could shake his mold with a circular motion so as to form a sheet in which the fibers lay impartially in all directions. Modern papermaking machine operators consider a 40/60 formation in the two directions as resulting in a well-balanced sheet, close to optimum for a mechanized process. Some evidence as to the effect of these differences will be discussed in the next chapter.

Sizing—For centuries before the period of this study, papers were sized with gelatine or glue, extracted from animal tendons, hides, etc., in order to prevent feathering of the ink. In 1678, John Evelyn, in a visit to a paper mill, observed that the paper is dipped in "allume water," presumably for hardening the gelatine size.[33] This is the earliest account of the use in England of a practice that is mentioned in the literature of papermaking throughout the 19th century. As the practice of papermaking developed, alum was introduced either in the beater at the "wet end" of the papermaking machine or in the tub-sizing operation after the formation of the paper.[3, 4, 34]

Unfortunately, alum is acidic, and is believed to be one of the primary causes of deterioration of paper after the mid-17th century.[18, 22] By further misfortune, papermaking became increasingly dependent upon alum, as is suggested in the papermaker's common expression, "There is almost no problem in papermaking that more alum will not cure."

The use of alum in combination with rosin to make an alum-rosin size, invented in Germany by Moritz Friedrich Illig in 1807,[19] gradually displaced gelatine/glue as the principal sizing material in the Occident. A principal advantage of the alum-rosin size was that it could be added to the pulp at the beater before it was formed into paper, thus eliminating the separate process of tub-sizing by which gelatine is applied after the paper is formed.

Although the histories of papermaking record that alum-rosin size was introduced to the United States about 1830,[19, 20] the data from the present study indicate infrequent use in book papers before the 1850's. After 1870, however, it was used almost universally (Tables 1, 3).

The reactions of alum and rosin vary with the conditions of papermaking and the quantities used. Alum (aluminum sulfate) is of course itself acidic and when used to excess promotes this condition in the paper. But even this characteristic is of minor importance compared to the liberation of sulfuric acid that takes place when the aluminum sulfate combines with the sodium resinate to form aluminum resinate (the water-repellent size), sodium sulfate and sulfuric acid. It is this reaction that often gives alum-rosin sized papers values of pH 4.2-5.0 as contrasted with values of pH 5.5-6.5 for tub-sized papers with gelatine/glue. And it is because of this reaction that the introduction of alum-rosin size contributed more to the deterioration of paper than any other development in papermaking of the 19th century, a contribution that persisted into the present century.[7, 34, 35]

Fillers (Loading Materials)—Although the practicability of using clay as a loading material for paper was established in England by William Cookworthy as early as 1733, it did not become generally used for that purpose until the 19th century.

By 1870 the use of clay as a loading material was common practice.[19] Hansard and Murray found the sulfates of calcium and barium in use as loading materials in England in the 1820's and described methods for the detection of these substances. They condemned the use of all sulfates as harmful to permanence.[3, 4]

The writers of the early 19th century intimate that loading materials were used to increase weight. By replacing fibers, however, they reduced strength. Modern fillers are looked upon favorably as contributing to the opacity of paper. They are in general either inert or can even buffer acid which would otherwise manifest itself. However, they have an abrasive action on the fibers when the paper is in use.

Coated Paper—Loading materials or fillers are added to the pulp before the formation of the paper. Coatings, by contrast, are applied to the substrate after it is formed. Coatings are added to provide a smooth or other special surface either for the sake of appearance, e. g., gloss, or to meet special press requirements such as for the printing of half-tone engravings. Although invented in the 18th century,[19] the use of coated papers in books (except for occasional plates) is largely a 20th century development and no examples are found in the book papers investigated in the present study. Some coatings are alkaline and contribute to the permanence of paper because they have a buffering effect upon the base papers sized with alum-rosin.

Groundwood Fibers—Even the increased supply of fiber promoted by the cotton gin could not meet the 19th century demand for more and cheaper paper. The long series of attempts to make paper economically from wood culminated in the groundwood process, invented in Germany by Friedrich Gottlob Keller in 1840 and introduced into the United States shortly thereafter. Groundwood is still a principal ingredient (about 75%) of newsprint.

Groundwood papers are generally weak and short-lived. On the one hand their weakness results from the fact that groundwood consists of minute chips of cellulose and non-cellulose material in an approximately 50/50 ratio. The latter serve primarily as filler and lack the fibril-bonding properties of well-prepared rag and chemical wood fibers. Their short life, on the other hand, derives from the fact that the non-cellulose materials break down into acidic compounds making this type of paper auto-destructive. The reaction is triggered by light, but even when protected from light and air (as in a bound volume) the life of newsprint may be limited to 15-20 years, while under full exposure to light and air it may last only a few weeks. Its deterioration may be still further hastened by other factors, such as alum-rosin size.

Many attempts were made by librarians after 1900 to prevent the deterioration of newspapers and other groundwood papers by sealing them from the air, but these attempts proved unsuccessful.[5] Meanwhile, we know from experience that cellulosic materials, if properly prepared, do not need to be excluded from the air but have endured for hundreds and even thousands of years.

Chemical Wood Paper—Although groundwood paper met a demand which could be satisfied by papers of low strength and poor appearance, the need still persisted for substitutes for rag fiber for book and writing papers.

The soda process for making paper by cooking wood chips in a solution of sodium hydroxide was developed in England by Hugh Burgess and Charles Watt in 1851, and patented in the United States in 1854.[19, 20, 88] In general, this process produced short fibers, lacked good purification methods as well, resulting in low strength. Nevertheless, soda fibers provided an acceptable extender of rag fibers and are found as a frequent ingredient of papers beginning in the 1850's.

The sulfite process, in which wood chips are cooked in a solution of sulfite of lime, was invented beginning in 1857 by Benjamin and Richard Tilghman of Philadelphia, and introduced on a commercial scale in the 1880's.[19] Although long strong fibers are now produced by this process, examples found during the present study are generally short and the paper made from them is weak (Table 1).

The sulfate process, in which wood chips are cooked in sodium sulfate, was invented in Germany by Carl F. Dahl in 1884,[19] but was not employed commercially in the United States during the 19th century.

Other Substitutes for Rag: Straw, Esparto—Over the years many sources of cellulose fibers have been found which are capable of being made into paper, and at one time or another many of these have been used commercially. At mid-19th century there were even in the United States several short-lived ventures for the manufacture of paper from Egyptian mummy-wrappings.[19] However, of the substitutes for rag other than wood, the most economically important are straw and esparto. Straw actually came into use before wood, since it does not require equally harsh chemical treatment; paper from straw was made at Chambersburg, Pennsylvania, in 1829 and American production was 100 tons a day in 1871.[19] It is found as an admixture in papers in the present study. Esparto is a North African grass known there and in France as alfa. It was first used in paper in England in the 1850's and was introduced into the United States in the 1860's.[19] It is more frequently found in English and French than in American papers and was not identified in the sample of this study.

The Jordan — Named for its inventor, Joseph Jordan, a Pennsylvanian, this machine was introduced in 1860 and used primarily to refine fibers further after working in the beater.[19, 20] Unfortunately, the Jordan was too often used to chop or shorten fibers, producing a weaker paper. Some thought this gave better printability; therefore, shortening the fibers became an acceptable practice. Some papermakers continue to harbor the misconception that printing papers do not need strength.[37]

Today, papermakers find that, with appropriate adjustments, this machine can be used to bruise the fibers so as to provide uniform fibrillation. Currently the Jordan is being used for this purpose in order to produce optimum flexibility in permanent/durable book papers.

IV. Discussion of the Test Data

The test data for the 500 books comprising the sample are presented in Table 1. The arrangement is by decade; within decades the specimens are ranked in ascending order of folding endurance values C. P. (Cross Printing) in the uninked areas.

Because the C. P. direction is the one in which principal folding and tearing stresses occur in books when actually in use, unless otherwise stated the test data cited will be for this direction.

The adequacy of the sample was checked in the following manner. For each decade, the median values of the folding endurance and tear resistance data of the first 25 papers tested were compared with the same values for all 50 papers after the second 25 were tested. As seen in Table 2, the differences between these sets of figures were negligible, and it was consequently concluded to be unnecessary to test additional specimens.

Because of the abnormalities that may affect individual books, conclusions have been based not upon data from single specimens, but instead upon median or average values from groups of books.

Based on the data of Table 1, the 500 papers of the study fall into three chronological groups, broadly differentiated by fiber content and method of sizing, as follows:

- The first group consists of papers for the years 1800-1849, composed entirely of rag fibers and with only 6 papers having alum-rosin size.
- The second group, 1850-1869, is in a transitional stage: the industrial revolution of papermaking. Fiber content varies from rag to chemical wood, sizing from gelatine/glue to alum-rosin.
- In the third group, 1870-1899, the papers are composed of rag, straw, groundwood and chemical wood fibers in varying amounts, and alum-rosin size predominates.

First Group, 1800-1849—Although papers of this period are the oldest, they are also the strongest of the three groups (Tables 1, 3). The exclusive use of rag fibers, the strongest of the fibers used for papermaking, offers an obvious explanation.

The importance of initial strength as a factor contributing to longevity is demonstrated in Fig. 1. There the deterioration regression lines of two papers are shown: one composed of strong rag fibers of high initial strength, the other composed of weak hardwood fibers prepared by the soda process. Both papers have the same rate of deterioration, as shown by the parallel regression lines, but the paper with the greater initial strength has a prospective useful life more than twice that of the weaker paper.

An estimate can be made of the original strength range of these papers by examining those which, because they are least acid, may be supposed to have lost least strength since their manufacture. In Table 9 are shown the results of testing the three strongest of the least acid papers of each decade. For the papers of the first group the average pH ranges from 5.5 to 8.0 and the folding endurance from 217 to 978 folds. The fiber content in all cases is rag.

While the papers of this group were the strongest of the three, they are much lower in strength than might be expected of all-rag papers and cannot be considered strong in any absolute sense. Their median folding endurance (18 to 35 folds) is in the newsprint category, and only one paper in twelve has a folding endurance above 200 folds. Even allowing for aging, these values are low as compared with the initial strength range of new strong all-rag papers in which the folding endurance is between 3,000 and 6,000 folds. They are also well below the values of the seven old papers, 1534-1722, with an average folding endurance of 396 folds, which were the subject of a previous study.[48]

Acidity—Although the median folding endurance of the 1800-1849 papers, with folds ranging from 0 to 1,483, represents the end-result of many different factors, in general their strength is in inverse proportion to their acidity. This relationship appears conspicuously in Table 3, where the median pH rises from 4.6 to 5.8 over the first five decades of the century, while the median folding endurance increases from 18 to 35 folds.

Similarly, of the 55 papers of the period having pH 6.0 or higher 58% have a folding endurance in excess of 50 folds, while of the 195 papers below pH 6.0 only 28% are within this strength category (Table 4).

These data raise questions both as to the source of the acidity and as to the cause of the improvement from 1800 to 1849.

As to the cause of the acidity, alum-rosin sizing can be exculpated as a general source, for it was found in only six of the papers. It seems likely, however, that alum used to harden the gelatin/glue size is a principal cause (see the discussion of residual chlorides and sulfates, below).

With respect to the general improvement over the period, it is natural to conclude that this is due to the decreasing age of the specimens. This conclusion is probably erroneous. The difference in age of 50 years can hardly account for the approximately six-fold difference in acidity. While it is difficult to determine the exact cause of the decrease in acidity during the last three decades of this period, it is quite possible that the findings of Murray had a decided effect on the papermakers. No further instances of books "CRUMBLING LITERALLY TO DUST" are reported. Murray made many contributions to the papermaking industry, but his detection of acidity in paper was the most significant. Perhaps his warnings on acidity, together with improvements in techniques, brought about increased quality in book papers.

Cotton vs. Linen—From this first group, 15 papers per decade, chosen at random, were analyzed for comparative content of cotton and linen fiber, with a view to ascertaining whether the increased production of cotton after the invention of the cotton gin had a significant effect upon the initial strength of papers by increasing the quantity and quality of clippings or worn rags available to the papermaker in other ways (Table 15). Unexpectedly, the cotton content remained at approximately the same (30%) level for the first four decades and did not increase significantly (to 65%) until the fifth decade.

However, because—as pointed out earlier—cotton fibers are more likely to be well fibrillated than flax, and since good fibrillation is conducive to good folding endurance, it may be supposed that some increase in strength may have resulted from the increased use of cotton. However, the evidence on this point is not clear.

Chlorides and Sulfates—Exploratory tests for chlorides and sulfates were made on ten of the strongest and ten of the weakest papers, 1800-1837 (Table 5).

Unexpectedly, small traces of chlorides were found in most papers. Known sources of chlorine are calcium hypochlorite used for bleaching rags and half stuff (pulp), and chlorine gas sometimes used to bleach finished paper.[3, 4, 23, 24] Since most chlorides are soluble it is believed that many were leached (soaked) out in the long soaking period and by agitation in the beater.

Sulfates may have originated from several sources. Early bleaching methods called for repeated soakings of cloth in lime water which contained extract of wood ashes, followed by rinses in a dilute solution of sulfuric acid or alum water.[21] Insoluble calcium sulfate, precipitated by this treatment, may have remained harmlessly in the fibers.

An even more probable source of sulfates is the alum (probably potassium aluminum sulfate) used to harden the gelatine/glue size. Alum was either introduced in the beater or added to the tub size.[3, 4, 34] The resultant sulfates would remain in the papers. The low pH found in most of the papers 1800-1849 can most likely be attributed to these sulfates.

A third possible source of sulfates, exemplified by specimen no. 502, is the use of gypsum (calcium sulfate) as a filler.[3, 4] There is no reason to suppose that this insoluble, near-neutral, and relatively inert substance is responsible for deterioration.

Second Group, 1850-1869—The 1850's and 1860's constitute a transition period in which straw and wood substitutes began to displace rag fiber, and in which cheap processing produced still other effects. The papers of the period show an enormous drop in strength from the previous period. The median folding strength of the papers of the 1860's is 77% below that of the 1840's—8 folds as compared with 35 (Tables 1, 3). Of the papers of the period having a pH 6.0 or more only 43% (as contrasted with 58% for the previous period) are stronger than newsprint (Table 4).

The strongest papers of the period continue (as might be expected) to be all-rag. But the test data disclose an unexpected situation: the median folding strength of even the all-rag papers of the 1850's is less than half that of the 1840's, and that of the 1860's has again dropped by more than a third (Table 6). Of the part-rag and no-rag papers of the period it can be said only that they are in an even worse plight.

What has happened? It is obviously not simply the substitution of non-rag for rag fiber that has caused the decline. We must look for other causes.

They are not far to seek. In the first place, the acidity of these papers has increased in inverse proportion to their strength. The mean acidity of the papers of the 1850's is double that of the 1840's (pH 5.4 to 5.1) and that of the 1860's is nearly doubled again (pH 5.1 to 4.9; Table 3).

In the second place these papers show increasingly wide use of alum-rosin size—a use affecting only 10% of papers in the 1840's, but 32% in the 1850's and 42% in the 1860's (Table 3).

In the third place there is a marked decline in the quality of fiber as exemplified by fiber length. Fiber of good length is found in 84% of the papers of the 1840's but in only 64% of papers of the 1860's (Table 3).

It may be assumed that the use of fiber of shorter length than was previously employed contributed to somewhat lower initial strength of papers but did not directly cause the rapid deterioration to present strength levels. The latter can, however, be fully accounted for by the increased acidity, and this in turn by the use of alum-rosin size. The connection between alum-rosin size and acidity is shown in Tables 7 & 8 where it is seen that all-rag papers of the period, if rosin-sized, are more acid than those not so sized.

So pervasive was the debasement of quality in the papers of this period that even the all-rag papers well on the alkaline side and with good fiber length show only half or less of the strength of papers with similar characteristics of previous decades (Table 9).

Third Group, 1870-1899—In the papers of this period the transition that commenced in the 1850's is brought to completion. Rag is rapidly losing its dominance as a constituent of book papers. In the final decade of the century all-rag paper disappears entirely from the sample; 80% of the papers are part-rag, but 20% are no-rag, composed instead of wood or straw fibers. The quality of fiber as measured by fiber length has continued to decline. The use of alum-rosin size has become all but universal. The century ends with papers of equally excessive acidity as those with which it began, and paper strength has reached an all-time low (Tables 1, 3).

Only two papers of the whole group retain a folding strength greater than that of newsprint; 10% of them are in newsprint category and 52% are below newsprint and are no longer fit for regular library use; 37% are in the restoration category (Table 4).

Until the present study it was not realized that the weakening of fiber and the widespread application of alum-rosin size occurred simultaneously with each other and with the introduction of wood fibers.

Since the last-mentioned occurrence figured more conspicuously than the others in the transition through which paper passed in the second half of the 19th century, wood fibers have received the greatest share of blame for the degradation of paper in that period. It can be seen that this was undeserved.

While the use of short fibers undoubtedly contributed to lowering of the initial strength of paper, poor length was not peculiar to wood fibers. The decline in fiber length is found in all-rag and part-rag as well as in no-rag papers (Table 8). The introduction of the Jordan after 1860 was another factor besides chemical processing contributing to the shortness of fibers.

What was the initial folding strength of the papers of this period? In an effort to suggest an answer to this question, the folding strength values of the three strongest of the least acid papers of each decade have been averaged. For the decades 1870-1899 a range of 12-90 folds was obtained (Table 9). On the assumption that the near-neutral characteristics of these papers have prevented much deterioration since their manufacture it may be concluded that these values approximate their original strength.

For the deterioration from initial to present strength the high acidity, due primarily to alum-rosin size, provides adequate explanation (Tables 8, 10, 11). A dramatic illustration of the relation of acidity to deterioration is found with respect to nine papers containing groundwood. Those with the highest acidity are in the zero-fold category, even though one of them contained 60% rag fibers, while those with lower acidity still retain considerable strength in spite of the groundwood (Table 12).

Just as for the previous period, the principal source of acidity of the papers of 1870-1899 is undoubtedly alum-rosin size, and it rather than wood fiber must bear the chief blame for the degradation of paper in this period.

Machine vs. Hand-Made Paper—It was mentioned in an earlier chapter that the Fourdrinier (continuous) papermaking machine has been suspected of affecting adversely the strength of paper because of its inability to make a "near square sheet," namely, a sheet in which the fibers lie equally in all directions, as was formerly obtainable in hand-made paper.

To test this conjecture, the ratio of the folding endurance in both directions (C.P. to W.P.) of the 50 papers of the decade 1800-1809 (when paper was still mostly hand-made) was compared with the same ratio for the 50 papers of the decade 1850-59 (when the papermaking machine had almost completely displaced the hand mold). The same 1:2 ratio was found for both decades, thus failing to find any superiority in this respect in the hand-made over the machine-made paper.

Effect of Printer's Ink—It has been established that the commonly used black writing ink of the 19th century contained sulphuric acid in varying amounts and that its use was injurious to paper.[22] The effects of printer's ink on paper has not, by contrast, been previously studied. The measurements made during the present study of the folding endurance of 500 book papers and of their pH values in both inked and uninked areas, as recorded in Table 1, have made it possible to reach some preliminary conclusions on this matter.

A 19th century printing ink consisted basically of carbon black and boiled linseed oil.[22, 38, 39] Soon after application to the paper the oil oxidized and polymerized to form an encrustation around the fibers of the paper. This, together with damage to the fibers by pressure from the type, may be suspected of reducing the flexibility of paper.

To estimate this reduction, if any, the 48 papers in the sample having a strength of 25 or more folds and with a difference between the inked and uninked areas of ±pH 0.1 or less were selected for evaluation. Specimens with a lower folding strength were eliminated as being likely to produce erratic values, while a greater pH difference was expected to reflect greater deterioration in one of the two areas. These sampling restrictions eliminated the papers made after 1850. As seen in Table 13, it was found that there was a 70% retention of folding endurance of the inked areas when compared with the uninked areas, indicating a decided loss (average of about 30%) due to encrustation of oil in the fibers, etc.

However, the data in Table 1 indicate that in some papers the inked areas are considerably more acid or alkaline than the uninked. This prompted an investigation of the effects that ingredients of ink other than carbon and oil might have on a paper's strength over a period of years. For this purpose, from the 160 papers in the sample having a strength of 25 or more folds the 21 were selected having a difference between the inked and uninked areas of ±pH 0.3 or more. These papers were retested (with an average of 32 strips each) for folding endurance values for the inked and uninked areas. The relatively large differences in pH could be expected to be reflected in greater differences in folding strength than was caused by mere encrustation.

The results are shown in Table 14. There it appears that the inked areas retain on the average only 40% of the folding strength possessed by the uninked areas. This is a 30% greater loss than was found to be due to encrustation (Table 13). It may thus be estimated that injurious ingredients in the ink have caused some 13% of the 160 papers having a strength of 25 or more folds to lose some strength.

To develop similar values for the papers with a strength of less than 25 folds would require much detailed testing. It may be assumed, however, that the values would be about the same for all papers. Nevertheless, because of the many variables involved such as thickness of sheet, amount of ink deposited, type pressure, etc., the values found must be considered to be only approximate.

However, it is worth noting that, in contrast to the effect of writing ink on manuscripts during the 19th century, no instances have been found of visible damage to paper by printer's ink during that century.

V. Remedial Measures

It is hoped that the findings of the present study may (a) provide some answers to the persistent questioning as to what happened to the book papers of the 19th century, (b) provide a basis for estimating the magnitude of the paper deterioration problem, (c) assist toward designing a preservation program, and (d) contribute toward an understanding of paper that will benefit from 19th century experience.

The Magnitude of the Paper Deterioration Problem—In Table 16 the 500 papers of the sample are categorized on the basis of the pH values of the uninked areas. It is seen that 8.4% of the total had a pH 7.0 and above, i.e., neutral or alkaline. There is every reason to expect such papers to be stable. An additional 7.4% of the total have a pH 6.0-6.9, i.e., near-neutral. It is believed that papers of this value are relatively stable. These two categories comprise 16% of the total. For the preservation of papers in these categories librarians need feel no immediate concern.

It is the papers below pH 6.0 for which concern must be felt and which must form the subject of a paper-preservation program if they are to survive to meet the needs of research. For these papers are unstable to greater or less degree and are deteriorating with greater or less rapidity. They comprise 421 of the 500 papers or 84% of the entire sample.

This 84% of the total is made up of 78% of the 1800-1849 group, 79% of the 1850-1869 group and 99% of the 1870-1899 group. The anticipated rates of deterioration, based on the pH values, can be classified as (a) 18% medium (pH 5.2-5.9), (b) 37.6% high (pH 4.6-5.1), and (c) 28.6% very high (pH 4.0-4.5).

In addition to highly acid papers, those with low folding endurance and tear resistance contribute to the count of unusable papers. Papers in the "easily torn category" or with a folding endurance of 0-1 fold are not suitable for regular library use (Table 1). By these criteria 153 papers constituting 31% of the total sample must be accounted as unusable, comprising 10% of the 1800-1849 group, 22% of the 1850-1869 group and 69% of the 1870-1899 group. Many others in the sample will reach the unusable category in a few decades unless previously deacidified.

Prevention of Deterioration—It is the conclusion of this and of other studies that acidity is a principal cause of deterioration in book paper. Consequently, the two best methods for extending the useful life of book papers are (a) to deacidify the acid papers, and (b) to store all papers at low temperature. These are discussed below. However, it should be said immediately that regardless of the benefits expected from cold storage, acid should in any case be eliminated from papers deserving optimum longevity, for although lower temperatures may decrease the activity of acid they do not completely inactivate it.

Determination of Papers Needing Deacidification—In general, all papers below pH 6.0 should be deacidified if they are to be preserved indefinitely. Since the degree of acidity doubles with each drop of 0.3 in pH value, the urgency for deacidification increases in the same proportion.

A fully reliable test for acidity requires that a sample of the paper be soaked in a solvent so as to produce an extract on which the test is made with a pH meter. Such a procedure is necessarily time-consuming and laborious, and simpler and quicker tests have been sought. These include surface tests with special electrodes for the pH meter, and colorimetric spot tests. However, surface tests on modern papers should be used with caution because coatings or surface sizings may have different characteristics from the interior of the paper.

The results of the chlorophenol-red test (described in the chapter on Tests) are reported in Table 1 where they can be compared with the results of cold extraction tests using the Beckman pH meter. The two sets of results are sufficiently close as to permit the spot test to be considered satisfactory for determining the need for deacidification of a 19th century book paper.

Deacidification Processes —This laboratory has developed three different methods designed to deacidify documents. Calcium compounds are used in one, and magnesium compounds in the other two. The condition of the document, the degree of desired effectiveness, and the economy of the process are all factors to be considered when a group of papers is treated.

One of the earliest, and probably one of the most effective methods of deacidification and stabilization of a deteriorated document, is soaking it in a solution of calcium hydroxide and then in a solution of calcium bicarbonate. The first solution neutralizes the acidity and the second carbonates any residual hydroxide in the paper. Special bronze screens are used to convey the deteriorated sheet in and out of the solutions. For the past twenty-five years this procedure, which is applicable only to separate sheets, has been used successfully for deacidifying documents before restoration by lamination. For a full description of this procedure, refer to item 22 of the bibliography.

The second method consists of soaking the sheets or leaves of a book in a concentrated solution of magnesium bicarbonate. This method, which requires that the book be unbound so as to permit handling sheet by sheet, is faster than the first method described above. Only leaves or sheets in relatively good condition are suitable for deacidification by this process. Procedures and laboratory test results may be found in item 7 of the bibliography.

The third method consists of spraying a fine mist of magnesium bicarbonate on the sheet and allowing enough time for it to migrate into the fibers of the paper. While this method does not give as high degree of stability as the previously described processes, it is much faster and therefore more economical. Studies by this laboratory indicate that it has good potential application to single sheets and to thin books without the removal of the binding. Thick books offer problems of drying and distortion of the spine. See item 40 of the bibliography.

Increased Stability After Deacidification—Deacidification may be expected to inhibit the principal cause of deterioration in book papers. Generally, the deteriorative agents other than acid are present only in small amounts. The exceptions are the non-cellulose components of groundwood, but acidity appears to be a factor in triggering a breakdown of these components (see Table 12 and the discussion on page 27). In any case, the number of hard-cover books made of paper containing groundwood appears to be small (Table 1).

Changes Caused by Deacidification—The visible changes caused by deacidification are relatively minor. Yellowed papers often lose some discoloration. A loss of the impression of the type often occurs but is observable only upon close examination. A slight increase in caliper (thickness) usually occurs as a result of the relaxation of the fibers while wet. Printer's ink is not affected by deacidification, but writings in other than printer's ink may possibly be affected. However, the discussion of these is outside the scope of the present study.

Nearly Unusable Papers—Many of the books in the present study possess a strength of only 0-1 fold. Such papers are no longer suitable for regular library use. However, even these can be preserved for future use in research.

Studies of this laboratory indicate that the folding endurance and tear resistance values of a paper continue to follow the same pattern after it has reached the restoration category as before. Thus, if it took 50 years for a paper to deteriorate from an initial 1000 folds to one fold, it would require another 50 years for it to deteriorate to 0.001 fold, a strength believed to be slightly above that of charred paper, i.e., near-dust. However, if the paper is deacidified when it still has one-fold strength, it may require some hundreds of years to reach the near-dust category. During this time it can be photographed, and if it is to be put to more severe use it can be deacidified and laminated with cellulose acetate film and a high grade tissue, a process which offers a satisfactory method of strengthening a weakened sheet.

Courses Open to the Librarian—As a result of this study the librarian may choose two courses of action for nineteenth century books containing high acidity.

The first course consists of leaving the volume in its original format and allowing a rapid rate of deterioration to reduce it to dust.

The second course is to tolerate a few barely observable changes through deacidification in order to increase the paper's longevity by many years.

Which course to choose is the librarian's decision. Each individual book presents different problems. Volumes free of acidity offer only those problems of furnishing good storage conditions, careful handling etc.

Storage at Low Temperatures—While the preservative effect of low temperatures is a matter of everyday experience, it remained for this laboratory to call attention to the converse of the situation—namely, to the highly deteriorative effect of the temperatures at which books are typically stored in American libraries.[7, 8, 41] This observation, which was prompted by accelerated aging tests, consisted of the tentative conclusion that the life expectancy of book paper is multiplied by a factor of approximately 4.5 with every drop in temperature of 15° C.

This laboratory is currently conducting experiments to ascertain more precisely the effect of temperature (and associated humidity) upon the life of paper and to design the arrangement for making practical use of this information. Meanwhile, evidence continues to accumulate supporting the desirability of low temperature storage for cellulose materials—e.g., the flora found in the mouths of mammoths frozen in the Siberian tundra 30,000 years ago,[18] the well preserved newspaper collections found in the unheated (ca. 45° F.) bookstacks of many European libraries,[42] and a book found frozen in the Antarctic in 1912 and recently recovered in excellent condition. Dr. F. Lyth Hudson, Senior Lecturer in Paper Science at the University of Manchester Institute of Science and Technology, Manchester, England, has recently turned over to this laboratory a portion of the book for further preservation in its deep freeze.[40]

VI. Summary

The purposes of this investigation were (a) to ascertain the present strength of 19th century book papers, (b) to identify the principal causes of deterioration, (c) to propose a simple method for identifying volumes requiring stabilization, and (d) to recommend appropriate methods of stabilization.

Fifty books for each decade, 1800-1899, representative of non-fiction trade books of the period and likely to be found in the collections of American research libraries, were assembled on a random (first come, first acquired) basis. Most were published in the United States; a few, especially for the early decades, were of British and Continental origin.

The adequacy of the sample was tested by comparing the findings for the first 25 books for each decade with those of all 50 books for the decade. It was found that the results of the second 25 did not significantly alter the findings reached with the first 25.

More than in any previous period, papermaking in the 19th century was affected by technological developments resulting from efforts to meet the ever-increasing demands for more and cheaper paper. Chapter III lists the more important of these developments from the view of their effect upon the permanence and durability of paper.

The tests applied to the papers in the course of the investigation are described in Chapter II. They included tests for folding endurance, tear resistance, acidity (two tests), presence of groundwood and rosin, as well as fiber analysis and a few special analyses (e.g. for chlorides and sulfates for selected specimens).

Based on the test data, the papers of the sample fall into three chronological groups, broadly differentiated by fiber content and method of sizing. The first group, 1800-1849, consists entirely of all-rag papers, all except six of which are sized with gelatine/glue. The second group, 1850-1869, is transitional: rag fiber was giving way to wood and gelatine/glue to alum-rosin sizing. In the third group, 1870-1899, the transition is completed; papers consist of rag, straw, groundwood and chemical wood in varying amounts, and alum-rosin size predominates.

The papers of the first group are the strongest of the three. Their median strength increases decade by decade from the first to the fifth decades of the century, commencing near the lower strength level of newsprint (18 folds) and ending near the upper (35 folds). This is, however, a much lower strength than we should be able to expect of all-rag papers. The immediate explanation is found in the acidity of these papers which, starting at a high level in the first decade (pH 4.6), gradually decreases to the fifth (pH 5.4). This acidity is probably in major part due to the use of alum in the sizing and other processes. The neutral papers of the group still retain, by contrast, much of what may be supposed to be their original strength. The evidence suggests that the poor condition of the papers of the first decade reflects the revolution in paper manufacture which took place around the turn of the century, while the improvement in the subsequent decades represents an adjustment to the new processes and materials.

The strength of the papers of the second group, 1850-1869, takes a plunge: for the 1850's it is less than half that of the 1840's and for the 1860's it has again been reduced by half (Table 3). Since this is the period in which wood fiber began to displace rag, a principal responsibility for the impairment of paper has been popularly imputed to wood. The test data do not bear this out. They show that the all-rag papers of the period (which are still in the majority) suffered the same sharp loss in strength as did the part-rag. Corresponding to the halving of strength in these papers was a doubling in acidity, together with the increasing use of alum-rosin size, and a trend toward the use of shorter fiber. It is concluded that these papers show the combined effects of lower initial strength due to poorer materials and of more rapid deterioration due to higher acidity. There is no doubt that the major source of the latter was alum-rosin size, which in this way contributed more to the deterioration of book paper than any other development in papermaking of the 19th century—a contribution which persists into the present century.

In the papers of the third group, 1870-1899, the tendencies observed in the second group are confirmed and fulfilled, and the transition to the use of cheaper fibers and manufacturing processes can be seen to be completed. For the papers of the final decade of the century the use of fiber of poor length has further increased, the use of alum-rosin size is all but universal, acidity has again doubled, and the median strength of papers has sunk to an all-time low, just above the restoration point. The correspondence between the increased use of alum-rosin size, increase in acidity and lack of strength constitutes impressive evidence of the causal relationship between the first and the last. Additional evidence of the role of acidity is furnished by the fact that even those papers of this period which contain groundwood retain a surprising amount of strength at lower acidity levels.

It has been suggested that the continuous papermaking machine contributed to the weakening of paper because it did not maintain, as did the hand process, a balance of strength between the two directions of the paper. A comparison of handmade papers of 1800-1809 and machine-made papers of 1850-1859 did not substantiate this suggestion.

The chlorophenol-red spot test was found to be reliable for identifying 19th century book papers lower than pH 6.0, and consequently needing stabilization. However, the spot test should not be expected to be reliable with coated and surface-sized papers.

Methods for stabilizing acid papers, described elsewhere by the present author, are mentioned and cited.

While writing ink used in the nineteenth century is known to be injurious to paper because of its sulfuric acid content, conclusions from this study indicate that printer's ink did no visible damage to the nineteenth century papers tested. There was, however, a loss of 30% in folding strength due to encrustation of the ink and some loss in 13% of the papers due to injurious ingredients (other than carbon and oil) in the ink.

This laboratory has previously called attention, in qualitative terms, to the deleterious effects on books of over-heated book stacks. It is now conducting experiments to measure more precisely the effects of storage temperature on books and to find practical applications for the information.

APPENDIX A

List of Books Tested 1800-1899

1800-1809

Sample No.

521. E. Gibbon. *The history of the decline and fall of the Roman empire.* v. 7. Philadelphia, 1805.
522. W. Russell. *The history of modern Europe.* v. 5. Philadelphia, 1801.
523. W. Russell. *The history of modern Europe.* v. 1. Philadelphia, 1800.
524. S. Smith. *Trial of Samuel Chase.* v. 11. Washington, 1805.
525. H. Flaccus. *Opera.* London, 1804.
526. J. Sansom. *American letters from Europe.* v. 2. Philadelphia, 1805.
527. A. Adam. *The world.* v. 4. Philadelphia, 1803.
528. T. Ruddiman. *The rudiments of the Latin tongue.* Trenton, 1805.
529. W. Russell. *The history of modern Europe.* v. 4. Philadelphia, 1802.
530. E. Gibbon. *The history of the decline and fall of the Roman empire.* v. 1. Philadelphia, 1804.
629. H. Corp. *An antidote to the miseries of human life.* New York, 1809.
630. J. Morse. *A new gazetteer of the eastern continent.* Boston, 1808.
648. V. Denon. *Travels in upper and lower Egypt.* v. 1. New York, 1803.
649. *The Federalist on the new constitution.* v. 1. New York, 1802.
650. M. De Bousmard. *Essai general de fortification.* v. 3. Paris, 1802.
656. M. Langles. *Recherches asiatiques ou memories.* Paris, 1805.
657. F. Buchanan. *A journey from Madras.* v. 2. London, 1807.
658. W. Russell. *The history of modern Europe.* v. 4. Philadelphia, 1800.
659. W. Russell. *The history of modern Europe.* v. 5. Philadelphia, 1802.
660. L. de Tousard. *American artillerist's companion.* v. 3. Philadelphia, 1809.
667. N. Wanostrocht. *Grammar of the French language.* Dublin, 1801.
668. S. Parker. *American citizen's sure guide.* Sag-Harbor, 1808.
669. F. Bacon. *Essays, moral, economical & political.* Boston, 1807.
670. J. Perrin. *Entertaining and instructive exercises.* New York, 1802.
671. D. Campbell. *A narrative of the extraordinary adventures.* New York, 1801.
672. T. Clarkson. *A portraiture of Quakerism.* Philadelphia, 1808.
673. F. Daudin. *Histoire naturelle generale et particulieri des reptiles.* v. 6. Paris, 1802.
938. J. Moore. *The young gentleman and lady's monitor.* Hartford, 1804.
939. *An epitome of the arts and sciences.* Philadelphia, 1804.
940. T. Smith. *The naturalists's cabinet.* London, 1807.
981. T. Gillet. *Essays on the theory and practice of the art of war.* v. 3. London, 1809.
982. T. Gillet. *Essays on the theory and practice of the art of war.* v. 2. London, 1809.
983. J. Miller. *A treatise containing the elementary part of fortification.* London, 1807.
984. H. Card. *History of the revolution of Russia.* London, 1803.

List of Books Tested 1800-1899

1800-1809

Sample No.

985. J. Burlamaqui. *The principles of natural & politic law.* v. 2. Cambridge, Mass., 1807.
986. *The American register or general repository.* v. 3. Philadelphia, 1808.
987. J. Marshall. *The life of George Washington.* v. 5. Philadelphia, 1807.
988. *The American register or general repository.* v. 4. Philadelphia, 1809.
989. G. Adams. *Lectures on natural and experimental philosophy.* v. 3. Philadelphia, 1807.
990. J. Chitty. *A treatise on pleading.* v. 2. New York, 1809.
991. E. Williams. *Report of cases argued & determined in the Supreme Judicial Court of the State of Massachusetts.* v. 1. Northampton, 1805.
992. G. Adams. *Lectures on natural and experimental philosophy.* v. 2 Philadelphia, 1806.
993. W. Broughton. *Voyage de decouvertes.* Paris, 1807.
994. *U. S. Journals of Congress.* Philadelphia, 1801.
995. H. St. John. *Letters on the study and use of history.* Paris, 1808.
996. W. Stenhouse. *Tables of simple interest.* London, 1806.
997. A. Adam. *The world.* v. 1. Philadelphia, 1803.
998. Bible. *Das Neue Testament.* Hagerstown, 1806.
999. P. Quillet. *Etat actuel de la legislation.* v. 2. Paris, 1805.
1000. P. Quillet. *Etat actuel de la legislation.* v. 1. Paris, 1805.

1810-1819

531. T. Smollett. *History of England.* v. 9. Edinburgh, 1810.
532. J. Mair. *Introduction to Latin syntax.* New York, 1811.
533. D. Hume. *The history of England.* v. 11. Edinburgh, 1810.
534. J. Ross. *Historiae.* Philadelphia, 1812.
535. G. Tomline. *Remarks on the refutation of Calvinism.* Philadelphia, 1817.
536. T. Smollett. *History of England.* v. 1. Albany, 1816.
537. C. Coote. *History of modern Europe.* v. 6. Philadelphia, 1811.
538. J. Rousseau. *Les confessions.* Paris, 1813.
539. *Second usurpation of Buonaparte.* v. 2. London, 1816.
540. W. Shakespeare. *Plays.* v. 1. London, 1811.
941. J. Buckingham. *The polyanthos.* v. 1. Boston, 1812.
942. T. Campbell. *Specimens of the British poets.* v. 6. London, 1819.
943. *Message from the president.* Washington, 1818.
944. H. Fielding. *Works.* v. 5. New York, 1814.
945. H. Fielding. *Works.* v. 2. New York, 1814.
946. I. Hill. *Rules and regulations for the field exercise.* Concord, 1817.
947. Pennsylvania. *Laws of the Commonwealth of Pennsylvania.* v. 4. Philadelphia, 1810.
948. A. Humboldt. *Political essays on the kingdom of New Spain.* v. 2. New York, 1811.

List of Books Tested 1800-1899

1810-1819

Sample No.

949. J. Monroe. *Message from the president.* Washington, 1816.
950. *U. S. Journal of the Senate.* Washington, 1816.
951. Pennsylvania. *Laws of the Commonwealth of Pennsylvania.* v. 2. Philadelphia, 1810.
952. A. de Moleville. *The history of Great Britain.* v. 4. London, 1812.
953. *U. S. State papers.* Washington, 1814.
954. *The Federalist on the new constitution.* Washington, 1818.
955. D. Hume. *The history of England.* v. 7. Edinburgh, 1810.
956. T. Morell. *An abridgement of Ainsworth's dictionary.* Philadelphia, 1818.
957. W. Muller. *The elements of the science of war.* London, 1811.
958. A. Humboldt. *Political essays on the kingdom of New Spain.* v. 1. New York, 1811.
959. Sallust. *Opera.* Philadelphia, 1814.
960. N. Dufief. *A new universal and pronouncing dictionary.* Philadelphia, 1810.
961. L. Murray. *Sequel to the English reader.* New York, 1817.
962. *Key to the exercise adapted to Murray's English grammar.* New York, 1815.
963. Bible. *Le Nouveau Testament.* Boston, 1811.
964. J. Redman. *The American dispensatory.* Philadelphia, 1818.
965. W. Shakespeare. *Works.* v. 3. Boston, 1810.
966. H. Blair. *Lectures on rhetoric and belles lettres.* New York, 1817.
967. L. Sterne. *Works.* v. 1. New York, 1813.
968. S. Lacroix. *An elementary treatise.* Cambridge, 1818.
969. D. Hume. *The history of England.* v. 8. Edinburgh, 1810.
970. *Letters of Junius.* v. 2. Philadelphia, 1813.
971. *Das gemeinschaftliche Gesangbuch.* Baltimore, 1818.
972. J. Swift. *Works.* v. 13. New York, 1812.
973. B. Jenks. *Prayers and offices of devotion.* Albany, 1817.
974. E. Clarke. *Travels in various countries of Europe, Asia & Africa.* New York, 1813.
975. T. Ruddiman. *The rudiments of the Latin tongue.* Philadelphia, 1818.
976. *U. S. Senate documents 1815-1816.* Washington, 1815.
977. *U. S. State papers.* Washington, 1817.
978. *U. S. Report of the Secretary of War, Dec. 7, 1818.* Washington, 1818.
979. *U. S. State papers and public documents.* Boston, 1819.
980. M. Marmontel. *Les Incas on la destruction.* 1817.

1820-1829

501. F. Butler. *A complete history of the United States.* v. 3. Hartford, 1821.
502. M. Hays. *Memoirs of queens.* London, 1821.

List of Books Tested 1800-1899

1820-1829

Sample No.

503. F. Antommarchi. *The last days of the emperor Napoleon.* v. 1. London, 1825.
541. A. Dickinson. *Gradus ad Parnassum.* Edinburgh, 1821.
542. T. Smollett. *History of England.* v. 5. Philadelphia, 1828.
543. J. Newton. *Works.* v. 3. New Haven, 1828.
544. G. Burder. *Village sermons.* v. 3. Philadelphia, 1825.
545. Plutarch. *Plutarch's lives.* v. 3. Philadelphia, 1822.
546. Homer. *Homer Ilias.* London, 1824.
547. J. Rousseau. *Oeuvres.* v. 1. Paris, 1822.
548. J. Rousseau. *Oeuvres.* v. 21. Paris, 1825.
549. J. Fried. *Enthultte Offenbarung Johannis oder vielmehr Jesus Christi.* Tubingen, 1829.
550. F. Butler. *History of the United States.* Hartford, 1821.
901. F. Gardua. *A Manual of the difficulties of the French language.* New York, 1829.
902. C. Ingersoll. *Conversations on English grammar.* Philadelphia, 1825.
903. Sallust. *DeCatilinae conjurationae.* New York, 1829.
904. J. Pierpont. *The national reader.* Boston, 1828.
905. L. Murray. *English grammar.* Bridgeport, 1824.
906. W. Grimshaw. *History of the United States.* Philadelphia, 1826.
907. H. Tanner. *Memoir on the recent surveys.* Philadelphia, 1829.
908. A. Levassiur. Lafayette in America. v. 1. Philadelphia, 1829.
909. A. Jamieson. *A grammar of rhetoric and polite literature.* New Haven, 1821.
910. J. Calvin. *Historical letters.* Georgetown, 1821.
911. U. S. Congress. *Secret journals of the acts and proceedings of Congress.* Boston, 1820.
912. C. De Martins. *Manuel diplomatique.* Paris, 1822.
913. C. Hatton. *A course of mathematics.* v. 2. New York, 1826.
914. Ovid. *Metamorphoseon Libri XV.* Philadelphia, 1823.
915. T. Randolph. *Memoir, correspondence, and miscellanies.* v. 3. Charlottesville, 1829.
916. W. Brown. *Antiquities of the Jews.* v. 1. Philadelphia, 1823.
917. U. S. Congress. *Secret journals of the acts and proceedings of Congress.* Boston, 1821.
918. J. Sherburne. *Life and character of the chevalier John Paul Jones.* New York, 1825.
919. J. Brannan. *Official letters of the military.* Washington, 1823.
920. S. Burch. *A digest of the laws of the City of Washington.* Washington, 1823.
921. *Relation d'um voyage a Bruxelles et a Coblentz (1791).* Paris, 1823.
922. A. Butler. *Lives of the fathers, martyrs.* v. 6. Philadelphia, 1822.
923 Cicero. *Orationes.* Philadelphia, 1826.
924. *The new monthly magazine.* v. 4. Boston, 1822.
925. A. Butler. *Lives of the fathers, martyrs.* v. 7. Philadelphia, 1822.

List of Books Tested 1800-1899

1820-1829

Sample
No.

926. H. Metcalf. *Deutsches Lesebuch fur Anfanger*. Boston, 1826.
927. Plutarch. *Plutarch's lives*. v. 4. Philadelphia, 1822.
928. J. Newton. *Works*. v. 14. New Haven, 1828.
929. J. Potter. *Archaeologia Graeca*. New York, 1825.
930. A. Lowe. *The Columbian class book*. Worcester, 1825.
931. J. Crawford. *Journal of an embassy*. London, 1828.
932. Virginia. *Journal of the House of Delegates*. Richmond, 1827.
933. Mexico. *Memoria del ramo de Hacienda Federal*. Mexico, 1826.
934. *Collections, topographical, historical relating principally to New Hampshire*. Concord, 1822.
935. C. Mercer. *A discourse on popular education*. Princeton, 1826.
936. *The rudiments of Latin grammar*. Boston, 1825.
937. V. Knox. *Elegant extracts*. v. 1. Boston, 1826

1830-1839

551. H. More. *Works*. v. 2. Philadelphia, 1832.
552. C. Wistar. *System of anatomy*. Philadelphia, 1830.
553. S. Smith. *Treatise on fever*. Philadelphia, 1831.
554. W. Adams. *The genuine epistles of the apostolic fathers*. Hartford 1834.
555. J. Milner. *History of the church of Christ*. Philadelphia, 1835.
556. Tacitus. *Works*. Philadelphia, 1836.
557. S. Bloomfield. *The Greek testament*. Boston, 1837.
558. J. Groves. *A Greek and English dictionary*. Boston, 1832.
559. *Library of useful knowledge, natural philosophy, II*. London, 1832.
560. J. Wardrop. *Curative effects of the abstraction of blood*. Philadelphia 1837.
861. *U. S. Resolutions, laws, and ordinances*. Washington, 1838.
862. B. Silliman. *The American journal*. New Haven, 1839.
863. "*Liberty*." [N. Y.?] 1837.
864. C. Bonnycastle. *Inductive geometry*. Charlottesville, 1834.
865. M. Clarke. *Cases of contested elections*. Washington, 1834.
866. A. Picken. *The club-book*. New York, 1836.
867. W. Duer. *Outlines of constitutional jurisprudence*. New York, 1833.
868. W. Sullivan. *The political class book*. Boston, 1831.
869. H. Martineau. *Retrospect of western travel*. v. 2. New York, 1838.
870. *U. S. General regulations for the army*. Washington, 1835.
871. P. Horry. *The life of General Francis Marion*. Philadelphia, 1834.
872. R. Whately. *Elements of logic*. New York, 1832.
873. Rhode Island Historical Society. *Collections*. Providence, 1835.
874. J. Davies. *Selections in pathology and surgery*. Philadelphia, 1839.
875. C. Jackson. *Second report in the geology of the state of Maine*. Augusta 1838.
876. Juvenal. *Satirae expurgate*. Boston, 1833.

List of Books Tested 1800-1899

1830-1839

Sample
No.

877. J. Abbott. *The young Christian.* New York, 1832.
878. A. Combe. *Principles of physiology.* New York, 1834.
879. P. Corneille. *Chefs-D'Oeuvre.* v. 1. Paris, 1838.
880. B. Gould. *Adam's Latin grammar.* Boston, 1832.
881. C. Rollin. *Ancient history.* v. 4. New York, 1839.
882. J. Bunyan. *The holy war.* Philadelphia, 1830.
883. L. Murray. *English grammar.* New York, 1838.
884. J. Pierpont. *The national reader.* Boston, 1836.
885. F. Leverett. *The new Latin tutor.* Boston, 1836.
886. J. Adams. *Jubilee of the Constitution.* New York, 1839.
887. *Military and naval magazine of the United States.* Washington, 1833.
888. N. Chipman. *Principles of government.* Burlington, 1833.
889. C. Buck. *Theological dictionary.* Philadelphia, 1835.
890. J. Marshall. *The life of George Washington.* v. 2. Philadelphia, 1838.
891. J. Marshall. *The life of George Washington.* v. 2. Philadelphia, 1833.
892. C. Gutzlaff. *Journal of two voyages.* New York, 1833.
893. *The Federalist on the new constitution.* Washington, 1831.
894. T. Fessenden. *Horticultural register and gardens magazine.* v. 2. Boston, 1836.
895. R. Mays. *Political sketches of eight years in Washington.* Baltimore, 1839.
896. E. Wines. *Two years and a half in the navy.* v. 1. Philadelphia, 1832.
897. J. Jones. *Memoirs of Rear Admiral Paul Jones.* v. 2. Edinburgh, 1830.
898. F. Haisler. *Comparison of weights and measures.* Washington, 1832.
899. J. Herschel. *The cabinet cyclopaedia.* London, 1833.
900. J. Barber. *Connecticut historical collections.* New Haven, 1836.

1840-1849

504. W. Irving. *Works.* v. 2. New York, 1849.
505. H. Trumball. *History of the Indian wars.* Boston, 1846.
506. L. von Ranke. *Memoirs of the house of Brandenburg.* London, 1849.
561. J. Macpherson. *The poems of Ossian.* New York, 1846.
562. H. White. *Elements of universal history.* Philadelphia, 1849.
563. F. Hemans. *Poems.* Philadelphia, 1845.
564. G. Spring. *The Bible not of man.* New York, 1847.
565. M. Seymour. *Mornings among the Jesuits at Rome.* New York, 1849.
566. S. Coleridge. *Biographia literaria.* New York, 1848.
567. L. Shelford. *Shelford on mortmain.* Philadelphia, 1842.
568. J. Mitford. *A treatise on the pleadings in the suits.* New York, 1844.
569. H. Walpole. *Letters.* v. 2. Philadelphia, 1844.
570. N. Chapman. *Lectures of the more important eruptive fevers.* Philadelphia, 1844.
674. W. Harvey. *Works.* London, 1847.
675. C. Edwards. *On receivers in chancery with precedents.* New York, 1846.

List of Books Tested 1800-1899

1840-1849

Sample
No.

676. N. Willis. *The poems, sacred, passionate and humorous.* New York, 1845.
677. R. Wooddesson. *Lectures on the laws of England.* v. 3. Philadelphia, 1842.
678. C. Williams. *Principles of medicine.* Philadelphia, 1848.
679. E. Robinson. *Harmony of the four gospels in Greek.* London, 1845.
680. T. Chalmers. *Miscellanies.* New York, 1848.
731. J. Bonncastle. *An introduction to mensuration.* Philadelphia, 1842.
732. C. Davies. *Elementary geometry.* New York, 1847.
733. H. Murray. *The encyclopedia of geography.* Philadelphia, 1845.
734. J. Fletcher. *Checks to antinomianism.* New York, 1846.
735. W. Horner. *Special anatomy and histology.* v. 2. Philadelphia, 1845.
736. J. Liebig. *Chemistry in its applications to agriculture and physiology.* New York, 1847.
737. T. Talfourd. *Literary sketches.* New York, 1848.
738. J. d'Aubigne. *History of the Reformation.* New York, 1847.
739. A. Jameson. *Characteristics of women.* Boston, 1846.
740. S. Goodrich. *Enterprise, industry and art of man.* Philadelphia, 1845.
841. F. Fenelon. *Les aventures de Telemaque.* Philadelphia, 1845.
842. J. Ryan. *An introduction to mensuration.* Philadelphia, 1844.
843. Maryland. *Journals of proceedings of the House of Delegates.* Annapolis, 1841.
844. L. Cheeseman. *Differences between old and new school.* Rochester, 1848.
845. C. Jackson. *First annual report on the geology of New Hampshire.* Concord, 1841.
846. W. Hickey. *The constitution of the U. S. of America.* Philadelphia, 1847.
847. H. Wheeler. *History of Congress.* New York, 1848.
848. *A dictionary of select and popular quotations.* 6th Amer. ed. Philadelphia, 1849.
849. J. Forster. *The statesmen of the Commonwealth of England.* New York, 1846.
850. *The American farmer.* Baltimore, 1846.
851. A. Cunningham. *The lives of the most eminent British painters.* New York, 1846.
852. W. Murrell. *Cruise of the frigate Columbia.* Boston, 1849.
853. C. Anthon. *A system of Latin.* New York, 1841.
854. W. Staples. *Annals of the town of Providence.* Providence, 1843.
855. J. d'Aubigne. *History of the Reformation.* New York, 1847.
856. R. Whately. *Elements of logic.* New York, 1847.
857. *The Nestorians of Persia.* Philadelphia, 1848.
858. M. Depping. *Histoire des Normands.* Paris, 1845.
859. A. Polson. *Law and lawyers.* London, 1840.
860. T. Macaulay. *The history of England.* London, 1849.

1850-1859

513. G. de Stael. *Corinne ou l' Italie.* New York, 1857.

List of Books Tested 1800-1899

1850-1859

No.
Sample
514. J. McClintock. *First book in Greek.* New York, 1855.
515. P. Bullions. *The principles of Latin grammar.* New York, 1850.
516. M. Huc. *Christianity in China.* v. 1. New York, 1857.
571. W. Prime. *Boat life in Egypt and Nubia.* 1857.
572. R. Foster. *Objections to Calvinism.* Cincinnati, 1856.
573. D. Webster. *Works.* v. 1. Boston, 1851.
574. S. Parton. *Fern leaves from Fanny's port-folio.* Buffalo, 1854.
575. J. Walker. *Essays on the intellectual powers.* Cambridge, 1851.
576. A. Pope. *The poetical works.* Boston, 1857.
577. W. Smithson. *The Methodist pulpit, South.* Washington, 1859.
578. D. Lardner. *Handbooks of natural philosophy.* Philadelphia, 1855.
579. A. Tooke. *Pantheon of the heathen gods.* Baltimore, 1852.
580. J. Mathews. *The Bible and men of learning.* New York, 1857.
661. J. Edwards. *Random sketches and notes of European travel in 1856.* New York, 1857.
662. J. Hope. *Leoni di Monota and other poems.* Philadelphia, 1857.
663. F. Gesenius. *Hebrew grammar.* 11th ed., New York, 1859.
664. A. Alexander. *Practical sermons.* Philadelphia, 1850.
665. H. Moore. *Works.* New York, 1855.
666. W. Bartlett. *Elements of natural philosophy.* New York, 1850.
721. E. Gibbon. *The history of the decline and fall of the Roman empire.* v. 2. Boston, 1856.
722. H. Hudson. *Lectures on Shakespeare.* New York, 1857.
723. W. Thackeray. *Punch's prize novelists.* New York, 1853.
724. W. Thackeray. *A shabby genteel story.* New York, 1852.
725. C. Spurgeon. *Sermons.* New York, 1858.
726. London Medical Soc. of Observation. *What to observe at the bedside.* Philadelphia, 1853.
727. H. Coleman. *European life and manners.* Boston, 1850.
728. T. Grimshawe. *A memoir of the Rev. Legh Richmond.* New York, 1857.
729. D. Lardner. *The museum of science and art.* v. 7 & 8. London, 1855.
730. L. Schmitz. *A history of Greece.* New York, 1851.
821. H. Bonar. *Hymns of faith and hope.* New York, 1857.
822. *Post-oak circuit.* Nashville, 1857.
823. M. Edgeworth. *Popular tales.* New York, 1853.
824. Cicero. *De officiis.* New York, 1852.
825. C. Zumpt. *A grammar of the Latin language.* New York, 1858.
826. P. Cottin. *Elisabeth ou les epilis de sibdrie.* New York, 1859.
827. M. Snead. *The I, II, III* Philippics. Boston, 1851.
828. W. Thomson. *The land and the book.* New York, 1859.
829. B. Taylor. *A visit to India, China and Japan.* New York, 1855.
830. W. Jay. *Works.* New York, 1855.
831. B. Bowen. *A blind man's offering.* New York, 1857.
832. C. McIlvaine. *The evidences of Christianity.* New York, 1853.
833. W. Lewis. *Confession of Christ.* New York, 1856.

List of Books Tested 1800-1899

Sample No.

834. G. Chouquet. *First lessons in learning French.* New York, 1853.
835. G. Ironside. *Historiae sacrae.* Philadelphia, 1856.
836. A. Oxenden. *Counsel to the Awakened.* Philadelphia, 1857.
837. F. Hemans. *Poetical works.* Boston, 1857.
838. G. Massey. *Poetical works.* Boston, 1857.
839. I. Leeser. *The twenty-four books.* Philadelphia, 1853.
840. J. James. *The window.* New York, 1853.

1860-1869

509. H. Von Sybel. *History of the French revolution.* London, 1867.
511. E. Litton. *The church of Christ.* New York, 1863.
512. G. Lewes. *Studies in animal life.* New York, 1860.
517. D. Mitchell. *My farm of Edgewood.* New York, 1867.
518. E. Charles. *Chronicles of the Schonberg-Cotta family.* New York, 1864.
581. J. Wilson. *Noctes Ambrosianae.* New York, 1863.
582. F. Williams. *English into French.* New York, 1860.
583. *A history of France.* New York, 1868.
584. J. Ryle. *Expository thoughts on the gospels.* New York, 1868.
585. Demosthenes. *Orations.* New York, 1860.
586. C. Yonge. *The clever woman.* New York, 1865.
587. L. Muhlbach. *Napoleon and the Queen of Prussia.* New York, 1867.
588. L. Muhlbach. *Prince Eugene.* New York, 1869.
589. G. Wood. *A treatise on therapeutics.* v. 1. Pennsylvania, 1868.
590. D. Mulock. *Christian's mistake.* New York, 1866.
651. J. Kurtz. *Text-book of church history.* Philadelphia, 1860.
652. W. Adams. *Conversations of Jesus Christ.* New York, 1868.
653. E. Erckmann. *Historie d'un conscrit.* Boston, 1869.
654. J. Ray. *Elements of algebra.* Chicago, 1866.
655. Juvenal. *Satires.* New York, 1860.
711. Terence. *Comoediae.* 1865.
712. A. Wister. *The old mam'selle's secret.* Philadelphia, 1869.
713. C. Giles. *Lectures on the incarnation.* New York, 1866.
714. Virgil. *Eclogues.* v. 2. New York, 1868.
715. W. Mason. *Manual of piety.* New York, 1868.
716. O. Fowler. *The practical phrenologists.* Boston, 1869.
717. Demosthenes. *The oration of Demosthenes on the crown.* Boston, 1868.
718. *Parlez-vous Francais?* New York, 1864.
719. L. White. *The changed cross.* New York, 1866.
720. U. S. Quartermaster Dept. *Roll of honor.* v. 4. Washington, 1868.
801. M. Jacobus. *Notes on the gospels.* New York, 1860.
802. E. Ogden. *Tariff or rates of duties.* New York, 1862.
803. H. Baird. *The life of the Rev. Robert Baird.* New York, 1866.
804. M. Kerney. *A compendium of ancient and modern history.* Baltimore, 1867.
805. J. Cooper. *Lionel Lincoln.* New York, 1869.
806. D. Kirkwood. *Meteoric astronomy.* Philadelphia, 1867.
807. T. Richards. *Appleton's companion handbook.* New York, 1864.
808. *The National Almanac for 1864.* Philadelphia, 1864.

List of Books Tested 1800-1899

1860-1869

Sample
No.

809. H. Mann. *Life of Horace Mann.* Boston, 1865.
810. J. Gibbons. *The banks of New York.* New York, 1864.
811. J. Willard. *Arion.* Boston, [1862?]
812. H. Pierson. *The old cabinet.* New York, 1861.
813. J. East. *My savior.* New York, 1865.
814. H. Greeley. *Essays.* Philadelphia, 1869.
815. C. Cutler. *A treatise on anatomy.* New York, 1860.
816. F. Moore. *Memorial ceremonies at the graves of our soldiers.* Washington, 1869.
817. J. Draper. *A history of the intellectual.* New York, 1863.
818. Massachusetts. *Report of the adjutant general.* Springfield, 1867.
819. U. S. Congress. *Executive documents.* Washington, 1863.
820. J. La Fontaine. *Fables.* New York, 1860.

1870-1879

507. D. Swing. *The trial of the Rev. Daniel Swing.* Chicago, 1874.
508. W. Stone. *History of New York City.* New York, 1872.
510. W. Hook. *Lives of the archbishops.* London, 1879.
591. G. Mac Donald. *Sir Gibbie.* Philadelphia, 1879.
592. C. Davies. *Elements of algebra.* New York, 1873.
593. H. Anderson. *Stories & Tales.* New York, 1876.
594. R. Broughton. *Goody-bye sweetheart.* New York, 1872.
595. J. Kurtz. *Text book of church history.* v. 4. Philadelphia, 1871.
596. Cicero. *Tusculan Disputations.* New York, 1877.
597. P. Bullions. *A practical grammar.* New York, 1871.
598. Sophocles. *Tragedies.* New York, 1877.
599. L. Manesca. *The serial and oral method of teaching languages.* Philadelphia, 1870.
600. C. Brace. *The races of the old world.* New York, 1871.
641. J. Tyndall. *The British association.* New York, 1875.
642. Members of the American Revision Committee. *Anglo-American Bible revisions.* Philadelphia, 1879.
643. E. Jones. *Exercises in Greek.* Part 1 and 2. Chicago, 1875.
644. E. Goulburn. *Thoughts on personal religion.* New York, 1870.
645. Demosthenes. *The Olynthiac and other public orations.* New York, 1872.
646. Cicero. *On oratory.* New York, 1872.
647. J. Keble. *The Christian year.* New York, 1872.
701. T. Huxley. *A manual of the anatomy.* New York, 1872.
702. J. Porter. *The Scottish chiefs.* Philadelphia, 1872.
703. J. Tautphoeus. *At odds.* Philadelphia, 1879.
704. Horace. *Works.* New York, 1877.
705. E. Otto. *Introductory German lessons.* New York, 1875.
706. C. Yonge. *Young folk's history of Germany.* Cincinnati, 1878.
707. Demosthenes. *Orations.* v. 2. New York, 1879.
708. Tacitus. *Works.* v. 1. New York, 1873.

List of Books Tested 1800-1899

1870-1879

Sample
No.

709. E. Bulwer-Lytton. *The Caxtons.* Philadelphia, 1876.
710. G. Sand. *Jealousy or Teverino.* New York, 1870.
781. F. Johnson. *The gospel according to Matthew.* New York, 1873.
782. L. Monroe. *Public & parlor readings.* Boston, 1875.
783. E. Whymper. *Scrambles amongst the Alps.* Philadelphia, 1873.
784. E. Coues. *Field ornithology.* Salem, 1874.
785. Xenophon. *Memorabilia of Socrates.* New York, 1871.
786. P. Hamerton. *Painter's camp.* Boston, 1875.
787. W. Carpenter. *Principles of mental physiology.* New York, 1874.
788. D. Fish. *Intermediate arithmetic.* New York, 1874.
789. J. Paget. *Judicial puzzles.* San Francisco, 1877.
790. J. Richter. *Titan.* Boston, 1873.
791. J. Westlake. *Common school literature.* Philadelphia, 1879.
792. Cicero. *Epistolae selectae.* New York, 1879.
793. L. Meredith. *Everyday errors of speech.* Philadelphia, 1873.
794. Sophocles. *Sophocles ex novissima recensione G. Dindorfii.* New York, 1871.
795. G. Powell. *Foundations and foundation walls.* New York, 1879.
796. E. Otto. *German conversation grammar.* New York, 1870.
797. E. Bulwer-Lytton. *Kenelm Chillingly.* New York, 1873.
798. Demosthenes. *Orations.* New York, 1873.
799. A. Gray. *Lessons in botany.* New York, 1873.
800. W. Aitken. *Science and practice of medicine.* v. 1. Philadelphia, 1872.

1880-1889

601. B. Pierre. *Paul and Virginia.* New York, 1884.
602. F. Stimson. *Guerndale.* New York, 1882.
603. L. Hickok. *Empirical psychology.* Boston, 1882.
604. Z. Ragozin. *The story of Chaldea.* New York, 1886.
605. G. Trevelyan. *Life and letters of Lord Macaulay.* v. 1. New York, 1880.
606. J. Burroughs. *Birds & poets.* Boston, 1887.
607. A. Gray. *Lessons in botany.* New York, 1881.
608. W. Boericke. *The twelve tissue remedies.* Philadelphia, 1888.
609. F. Crawford. *Saracinesca.* New York, 1887.
610. J. Lord. *Beacon lights of history.* New York, 1883.
631. M. Holley. *Samantha at Saratoga.* New York, 1887.
632. H. Bushnell. *Building eras.* New York, 1881.
633. W. Kip. *The history, object and proper observance.* New York, 1881.
634. A. Stanley. *Westminster sermons.* New York, 1882.
635. J. Parker. *The people's Bible.* v. 1. New York, 1886.
636. J. Parker. *The people's Bible.* v. 8. New York, 1888.
637. J. Parker. *The people's Bible.* v. 11. New York, 1886.
638. L. de La Ramee. *A village commune.* v. 5. New York, 1889.

List of Books Tested 1800-1899

1880-1889

Sample
No.

689. C. Sajous. *Annual of the universal medical sciences.* v. 3. Philadelphia, 1888.
690. R. Storrs. *The divine origin.* New York, 1884.
691. Cicero. *Three books of offices.* New York, 1886.
692. M. Oliphant. *The makers of Venice.* New York, 1889.
693. Xenophon. *Anabasis.* New York, 1887.
694. J. Parton. *Daughters of genius.* Philadelphia, 1888.
695. W. Hooker. *The child's book of nature.* New York, 1883.
696. A. Harkness. *Latin grammar.* New York, 1887.
697. P. Janet. *Elements of morals.* New York, 1887.
698. W. Kirkus. *Religion.* New York, 1886.
699. A. Marks. *Characteristics of the church.* New York, 1881.
700. Bible. *The New Testament.* New York, 1889.
761. T. Tasso. *Jerusalem delivered.* New York, 1881.
762. L. Lillie. *The household of Glen Holly.* New York, 1888.
763. C. DuBois-Melly. *The history of Nicolas Muss.* New York, 1888.
764. W. Scott. *Marmion.* Boston, 1885.
765. T. Chase. *The histories of living.* Philadelphia, 1884.
766. E. Arnold. *The light of Asia.* Boston, 1888.
767. P. Brooks. *Helps by the way.* Boston, 1886.
768. W. Whitney. *A brief German grammar.* New York, 1885.
769. H. Alford. *The Queen's English.* New York, 1884.
770. E. Bulwer-Lytton. *Lucile.* Boston, 1884.
771. A. Gennevraye. *L'ombra.* New York, 1887.
772. G. Stuart. *Select orations.* Philadelphia, 1883.
773. Bible. *The New Testament.* New York, 1880.
774. Archaeological Institute of America. *Papers.* v. 1. Boston, 1885.
775. J. Parker. *The people's Bible.* v. 7. New York, 1887.
776. C. Levermore. *Political history.* Boston, 1889.
777. J. Comegys. *Memoir of John M. Clayton.* Delaware, 1882.
778. J. Harrison. *French syntax.* Philadelphia, 1886.
779. J. Bruce. *The year book of treatment.* Philadelphia, 1889.
780. A. Barr. *The bow of orange ribbon.* New York, 1886.

1890-1899

519. J. Mitchell. *Two old faiths.* New York, 1892.
520. H. Jones. *Medical electricity.* Philadelphia, 1895.
611. I. De Saint-Amand. *Citizeness Bonaparte.* New York, 1894.
612. J. Ward. *Naturalism and agnosticism.* New York, 1899.
613. H. Howe. *A study of the sky.* Meadville, Pa., 1896.
614. B. Taylor. *Library of travel.* New York, 1893.
615. C. Young. *The sun.* New York, 1896.
616. M. Le Normand. *Historical and secret memoirs.* v. 1. Philadelphia, 1890.

List of Books Tested 1800-1899

1890-1899

Sample
No.

617. H. Beers. *Initial studies in American letters.* New York, 1891.
618. L. De Bourrienne. *Memoirs of Napoleon Bonaparte.* v. 3. New York, 1894.
619. C. Ransome. *A short history of England.* New York, 1890.
620. J. Harrison. *The story of the nations.* New York, 1897.
621. S. Grand. *The heavenly twins.* New York, 1893.
622. R. Stevenson. *Prince Otto.* New York, 1898.
623. J. Parker. *The people's Bible.* v. 1. New York, 1891.
624. C. Neiswanger. *Electro therapeutical practice.* Chicago, 1898.
625. A. Bacon. *Japanese girls and women.* Boston, 1891.
626. W. Patton. *A practical treatise.* New York, 1893.
627. A. Ritchie. *Chapters from some unwritten memoirs.* New York, 1895.
628. S. Tillman. *Descriptive general chemistry.* New York, 1899.
681. R. Blackmore. *Kit and Kitty.* New York, 1890.
682. E. Bulwer-Lytton. *Lucile.* New York, 1892.
683. W. Black. *The handsome Humes.* New York, 1894.
684. C. Warner. *That fortune.* New York, 1899.
685. F. Kelsey. *Select orations.* Boston, 1898.
686. W. Towles. *Descriptive anatomy.* Charlottesville, 1898.
687. H. Bunner. *Short sixes.* New York, 1891.
688. R. Davis. *Soldiers of fortune.* New York, 1897.
689. J. Illingworth. *Divine immanence.* New York, 1898.
690. E. Bowser. *An elementary treatise.* New York, 1890.
741. W. Curtis. *The United States and foreign powers.* Meadville, Pa., 1892.
742. R. Davis. *A year from a reporter's note-book.* New York, 1898.
743. D. Hoyt. *The world's painters.* Boston, 1898.
744. H. Chambers. *A higher history of the United States.* New York, 1898.
745. H. Wood. *Ideal suggestion through mental photography.* Boston, 1899.
746. J. Harrison. *The story of the nations.* London, 1890.
747. Goethe. *Einfuhrung in Goethe's Meisterwerke.* Boston, 1899.
748. H. Dresser. *The power of silence.* Boston, 1895.
749. W. Byerly. *An elementary treatise.* Boston, 1893.
750. E. Wilson. *Mountain climbing.* New York, 1897.
751. C. Warner. *That fortune.* New York, 1899.
752. F. Parker. *Kellogg's teacher's library.* v. 3. New York, 1896.
753. W. Allen. *Ancient history.* Boston, 1891.
754. W. Mallock. *The heart of life.* New York, 1895.
755. R. Stevenson. *Vailima letters.* v. 1. Chicago, 1895.
756. C. Sauer. *Italian conversation grammar.* New York, 1899.
757. T. Munger. *On the threshold.* Boston, 1898.
758. J. Stalker. *Imago Christi.* New York, 1890.
759. H. Roby. *A grammar of the Latin language.* New York, 1896.
760. M. Oliphant. *The makers of Venice.* New York, 1898.

APPENDIX B

TABLES

Special Abbreviations and Terms Used in the Tables

Area of paper
- *Inked*—printed area
- *Uninked*—unprinted area

Direction of test
- *C. P.*—Cross Printing, i.e., line of test at right angles to the lines of printing.
- *W. P.*—With Printing, i.e., line of test parallel to the lines of printing.

Fiber
- *C. W.*—Chemical wood
- *G. W.*—Groundwood
- *H. W.*—Hardwood
- *R.*—Rag
- *S.*—Straw
- *S. W.*—Softwood

Folding test
- *M. I. T.*—Massachusetts Institute of Technology Fold Endurance Tester. See Chapter II.

Letters following specimen numbers
- *A*—American publication
- *B*—British publication
- *E*—Continental publication

pH
- *Cold extr.*—Cold extraction. See Chapter II.

Spot test
- *Chlor.*—Chlorophenol-red
- *s. purple*—Slight purple

Tear test
- *Elmendorf*—Elmendorf Tear Tester—See Chapter II.
- *Easily torn cat.*—Easily torn category, measured in grams tear (Elmendorf). See Chapter II.
- *Underscoring* of tear test values identifies papers having values within the easily torn category.

Table 1

The number of folds (M.I.T. 1/2 kg. tension), basis weight, easily torn category, tear resistance (grams Elmendorf), chlorophenol spot test, pH (cold extraction), presence of rosin (Raspail Test) and type of fiber for 500 book papers 1800-1899 arranged by decade.

1800-1809

		No. Folds (M.I.T. 1/2 kg. T.)					Gr. Tear (Elmendorf)			pH (Cold Ext.)				
		Uninked		Inked	Basis	Easily Torn			Chlor. spot	Un-				
No.	Year	C.P.	M.P.	C.P.	Wt.	Cat.	C.P.	M.P.	test	inked	Inked	Rosin	Fiber (in %)	Length
667B	1801	1	1	0	35	14	12.4	13.8	yellow	4.3	4.4	N	100R	Good
630A	1808	1	1	1	43	17	14.0	18.8	"	4.2	4.1	"	"	"
671A	1801	2	2	2	53	19	21.6	16.8	"	4.1	4.1	"	"	"
994A	1801	2	1	2	51	19	21.4	22.2	"	4.4	4.4	"	"	"
657B	1807	2	1	1	53	19	9.8	17.0	"	4.2	3.9	"	"	"
985A	1807	3	3	2	47	17	17.0	20.2	"	4.1	4.0	"	"	"
629A	1809	3	5	3	43	17	25.2	31.6	"	4.6	4.5	"	"	"
658A	1800	5	5	3	57	23	18.0	19.6	"	4.2	4.0	"	"	"
938A	1804	6	4	7	44	17	24.8	21.8	"	4.6	4.4	"	"	"
868A	1808	6	3	7	35	14	31.4	25.6	"	4.4	4.4	"	"	"
990A	1809	8	7	6	47	17	28.0	28.8	"	4.4	4.3	"	"	"
988A	1809	8	3	3	44	17	27.6	24.4	"	4.5	4.3	"	"	"

Table I (continued)

1800-1809

No.	Year	No. Folds (M.I.T. ½ kg. T.) Uninked C.P.	M.P.	Inked C.P.	Basis Wt.	Easily Torn Cat.	Gr. Tear (Elmendorf) C.P.	M.P.	Chlor. spot test	pH (Cold Ext.) Un-inked	Inked	Rosin	Fiber (in %)	Length
981B	1809	9	6	4	53	19	21.6	22.8	yellow	4.4	4.2	N	100R	Good
523A	1800	11	9	8	45	17	25.0	23.2	"	4.3	4.5	"	"	"
659A	1802	11	11	6	51	19	24.6	28.4	"	4.1	4.0	"	"	"
528A	1805	11	8	15	38	14	29.6	24.2	"	5.3	5.3	"	"	"
996B	1806	11	7	11	56	23	35.2	32.0	"	4.5	4.3	"	"	"
982B	1809	11	7	4	58	23	28.8	24.0	"	4.4	4.3	"	"	"
522A	1801	12	9	3	53	19	15.2	18.6	"	4.2	4.0	"	"	"
648A	1803	13	5	13	48	19	30.4	29.4	"	4.8	4.6	"	"	"
673E	1802	14	12	15	39	16	24.4	37.8	"	5.2	5.2	"	"	"
858A	1804	14	4	13	41	16	23.2	23.2	"	4.9	4.8	"	"	"
521A	1805	14	18	13	48	19	21.8	41.0	"	4.7	4.6	"	"	"
526A	1805	14	15	13	57	23	25.6	28.4	"	4.9	5.1	"	"	"
680A	1809	15	5	11	44	17	28.8	23.8	"	4.7	4.6	"	"	"

Table 1 (continued)

1800-1809

		No. Folds (M.I.T. ½ kg. T.)					Gr. Tear (Elmendorf)			pH (Cold Ext.)				
		Uninked		Inked										
No.	Year	C.P.	W.P.	C.P.	Basis Wt.	Easily Torn Cat.	C.P.	W.P.	Chlor. spot test	Un-inked	Inked	Rosin	Fiber (in %)	Length
529A	1802	17	16	8	53	19	24.2	26.6	yellow	4.3	4.2	N	100R	Good
649A	1802	20	16	18	56	23	38.6	38.4	"	4.6	4.3	"	"	"
998A	1806	21	5	14	40	16	28.6	30.4	"	4.5	4.4	"	"	"
986A	1808	24	8	14	43	17	21.4	24.0	"	4.4	4.4	"	"	"
984B	1803	30	32	29	46	17	32.6	33.6	"	4.6	4.5	"	"	Medium
991A	1805	30	34	16	48	17	27.0	31.6	"	4.5	4.5	"	"	Good
993E	1807	33	41	22	46	17	37.4	40.0	"	5.6	5.6	"	"	"
1000E	1806	34	55	23	38	16	41.2	49.4	"	6.0	5.7	"	"	"
669A	1807	37	15	25	47	17	44.4	41.2	"	4.9	4.7	"	"	"
999E	1805	38	66	34	40	16	41.8	58.8	"	5.6	5.4	"	"	"
983B	1807	43	25	24	48	17	59.4	50.6	"	5.5	5.6	"	"	"
530A	1804	53	33	45	51	19	33.4	34.8	"	5.0	5.2	"	"	"
992A	1806	62	49	45	54	19	41.6	35.6	"	4.6	4.6	"	"	Medium

Table 1 (continued)

1800-1809

		No. Folds (M.I.T. ½ kg. T.)					Gr. Tear (Elmendorf)			pH (Cold Ext.)				
		Uninked		Inked										
No.	Year	C.P.	W.P.	C.P.	Basis Wt.	Easily Torn Cat.	C.P.	W.P.	Chlor. spot test	Un-inked	Inked	Rosin	Fiber (in %)	Length
672A	1808	62	49	58	50	19	39.2	43.8	yellow	5.0	4.7	N	100R	Good
987A	1807	67	100	60	49	19	35.4	45.4	"	5.4	5.4	"	"	"
940B	1807	92	74	143	43	17	42.0	42.6	"	4.8	5.0	"	"	"
656E	1805	116	48	101	53	19	46.8	41.8	purple	7.1	7.0	"	"	"
997A	1803	127	97	89	46	19	43.2	31.4	yellow	4.8	4.7	"	"	"
650E	1802	180	28	83	41	16	33.8	28.6	"	5.1	5.1	"	"	"
524A	1805	194	235	133	49	19	48.4	45.0	"	4.6	4.5	"	"	"
670A	1802	211	57	222	46	17	55.6	53.8	purple	5.9	6.0	"	"	"
525B	1804	243	123	129	40	16	40.0	41.4	yellow	5.5	5.1	"	"	"
527A	1803	278	111	135	47	17	45.6	42.2	"	5.0	5.1	"	"	"
995E	1808	323	207	262	53	19	42.2	47.4	"	6.0	6.0	"	"	"
989A	1807	750	535	396	48	19	28.2	28.2	yellow	4.4	4.3	"	"	"

Table 1 (continued)

1810-1819

		No. Folds (M.I.T. ½ kg. T.)					Gr. Tear (Elmendorf)			pH (Cold Ext.)				
		Uninked		Inked	Basis	Easily Torn			Chlor. spot					
No.	Year	C.P.	M.P.	C.P.	Wt.	Cat.	C.P.	M.P.	test	Un-inked	Inked	Rosin	Fiber (in %)	Length
962A	1815	1	1	1	39	16	12.0	9.2	yellow	4.4	4.2	N	100R	Good
941A	1812	3	3	4	53	19	17.0	23.0	"	4.3	4.2	"	"	"
965A	1810	4	3	4	44	17	27.4	27.0	"	4.8	4.5	"	"	Medium
957B	1811	6	4	3	48	19	12.8	16.0	"	4.1	3.9	"	"	Good
967A	1813	6	4	4	49	19	23.2	22.0	"	4.4	4.3	"	"	"
534A	1812	6	6	4	35	14	12.8	14.0	"	4.6	4.2	"	"	"
952B	1812	7	5	3	50	19	14.4	18.2	"	4.1	3.9	"	"	"
944A	1814	8	5	6	39	16	17.2	19.2	"	4.1	4.0	"	"	"
535A	1817	8	5	4	54	19	11.4	29.0	"	4.2	4.4	"	"	"
947A	1810	8	6	6	47	17	24.8	25.4	"	4.3	4.2	"	"	"
970A	1813	8	12	5	44	17	39.2	34.8	"	4.8	4.6	"	"	"
969B	1810	9	11	5	44	17	18.4	15.0	"	4.2	4.0	"	"	"

Table 1 (continued)

1810-1819

		No. Folds (M.I.T. ½ kg. T.)					Gr. Tear (Elmendorf)			pH (Cold Ext.)				
		Uninked		Inked										
No.	Year	C.P.	W.P.	C.P.	Basis Wt.	Easily Torn Cat.	C.P.	W.P.	Chlor. spot test	Un-inked	Inked	Rosin	Fiber (in %)	Length
963A	1811	10	6	5	38	16	20.2	19.4	yellow	4.3	4.3	N	100R	Good
955B	1810	11	8	6	45	17	16.0	13.6	"	4.2	4.0	"	"	"
968A	1818	11	7	7	44	17	20.8	19.6	"	4.2	4.1	"	"	"
971A	1818	11	7	7	44	17	24.8	28.0	"	4.7	4.6	"	"	"
946A	1817	12	14	7	36	14	33.0	29.0	"	4.6	4.4	"	"	"
975A	1818	13	6	13	44	17	40.8	41.8	"	5.2	5.0	"	"	"
533B	1810	15	13	14	43	17	16.4	22.4	"	4.4	4.3	"	"	" "
532A	1811	16	15	15	39	16	23.2	20.4	"	4.9	4.5	"	"	"
531B	1810	17	13	10	47	17	17.8	18.0	"	4.5	4.2	"	"	"
974A	1813	18	30	22	55	23	28.0	41.6	"	5.0	4.7	"	"	"
976A	1815	19	5	5	47	17	15.0	15.6	"	4.1	4.0	"	"	"
540B	1811	19	22	16	51	19	24.0	30.0	"	4.7	4.5	"	"	Medium
538E	1813	21	13	15	34	14	20.0	20.0	"	4.7	4.6	"	"	Good

Table 1 (continued)

1810-1819

		No. Folds (M.I.T. ½ kg. T.)					Gr. Tear (Elmendorf)			pH (Cold Ext.)				
		Uninked		Inked										
No.	Year	C.P.	W.P.	C.P.	Basis Wt.	Easily Torn Cat.	C.P.	W.P.	Chlor. spot test	Un-inked	Inked	Rosin	Fiber (in %)	Length
943A	1818	23	14	9	43	17	18.4	22.6	yellow	4.6	4.3	N	100R	Good
953A	1814	24	19	18	44	17	31.2	29.6	"	4.7	4.5	"	"	"
945A	1814	27	21	19	44	17	29.6	31.6	"	4.6	4.4	"	"	"
950A	1816	27	27	13	48	19	21.6	24.0	"	4.6	4.5	"	"	"
979A	1819	27	17	10	43	17	15.2	24.2	"	4.8	4.3	"	"	"
961A	1817	27	18	22	42	16	32.6	23.4	"	5.2	5.0	"	"	"
956A	1818	28	15	21	43	17	25.4	33.4	"	4.8	4.5	"	"	"
966A	1817	30	16	13	42	16	22.6	21.2	"	4.8	4.3	"	"	"
951A	1810	33	10	14	43	17	38.0	24.8	"	4.5	4.4	"	"	"
960A	1810	37	14	26	42	16	33.2	30.8	"	4.8	4.6	"	"	"
949A	1816	40	16	16	47	17	22.6	23.8	"	4.7	4.3	"	"	"
539B	1816	47	18	44	48	19	34.8	37.4	"	4.8	4.6	"	"	Medium
977A	1817	50	31	17	44	17	20.0	25.2	"	5.2	4.8	"	"	Good

Table 1 (continued)

1810-1819

		No. Folds (M.I.T. ½ kg. T.)					Gr. Tear (Elmendorf)			pH (Cold Ext.)				
		Uninked		Inked										
No.	Year	C.P.	W.P.	C.P.	Basis Wt.	Easily Torn Cat.	C.P.	W.P.	Chlor. spot test	Un-inked	Inked	Rosin	Fiber (in %)	Length
959A	1814	51	37	22	37	14	29.2	37.4	yellow	4.9	4.6	N	100R	Good
972A	1812	53	28	19	46	17	30.0	26.2	"	4.7	4.5	"	"	"
954A	1818	55	25	22	46	17	23.2	25.4	"	5.0	4.8	"	"	"
980E	1817	63	44	25	41	16	31.6	40.0	"	5.2	5.3	"	"	"
973A	1817	68	29	34	38	16	35.2	32.0	"	5.4	4.9	"	"	"
948A	1811	69	21	28	49	19	30.8	30.0	"	4.5	4.3	"	"	"
536A	1816	70	44	19	47	17	22.6	23.4	"	4.7	4.2	"	"	"
942B	1819	88	61	48	48	19	34.4	36.6	"	4.7	4.6	"	"	"
978A	1818	91	24	42	42	16	34.0	31.2	"	4.7	4.6	"	"	"
958A	1811	119	49	57	51	19	35.2	33.2	"	5.0	4.8	"	"	"
537A	1811	154	149	102	42	16	33.6	41.8	"	5.2	4.7	"	"	"
964A	1818	433	231	135	46	17	31.8	35.4	s.purple	6.5	6.1	"	"	"

Table 1 (continued)

1820–1829

		No. Folds (M.I.T. ½ kg. T.)					Gr. Tear (Elmendorf)			pH (Cold Ext.)				
		Uninked		Inked										
No.	Year	C.P.	W.P.	C.P.	Basis Wt.	Easily Torn Cat.	C.P.	W.P.	Chlor. spot test	Un-inked	Inked	Rosin	Fiber (in %)	Length
501A	1821	1	0	0	41	16	7.4	7.4	yellow	4.2	3.6	N	100R	Poor
934A	1822	2	1	2	42	16	12.2	11.2	"	4.0	3.9	"	"	Good
911A	1820	2	1	0	57	23	13.0	18.0	"	4.2	4.0	"	"	"
502B	1821	2	2	5	52	19	8.8	11.4	"	4.2	4.0	"	"	Medium
905A	1824	3	3	5	57	23	41.6	26.6	"	4.5	4.5	"	"	Good
928A	1828	4	1	1	50	19	10.4	8.2	"	4.2	4.0	"	"	"
910A	1821	4	2	4	46	17	20.2	23.6	"	4.8	4.6	"	"	"
930A	1825	5	4	4	47	17	23.8	22.8	"	4.1	4.0	"	"	"
932A	1827	5	10	4	42	16	18.8	24.2	"	4.6	4.3	"	"	"
936A	1825	5	11	5	44	17	22.0	28.2	"	5.0	4.9	"	"	"
937A	1826	6	3	4	41	16	19.8	23.4	"	4.5	4.1	"	"	"
547E	1822	7	11	8	34	14	26.0	31.2	s.purple	6.7	6.3	"	"	Medium

Table 1 (continued)

1820-1829

No.	Year	No. Folds (M.I.T. ½ kg. T.) Uninked C.P.	No. Folds (M.I.T. ½ kg. T.) Uninked W.P.	No. Folds (M.I.T. ½ kg. T.) Inked C.P.	Basis Wt.	Easily Torn Cat.	Gr. Tear (Elmendorf) C.P.	Gr. Tear (Elmendorf) W.P.	Chlor. spot test	pH (Cold Ext.) Un-inked	pH (Cold Ext.) Inked	Rosin	Fiber (in %)	Length
919A	1823	9	4	3	44	17	14.4	16.8	yellow	4.6	4.3	N	100R	Good
925A	1822	9	8	10	52	19	31.6	26.4	"	5.9	5.6	"	"	"
902A	1825	10	7	14	37	14	14.6	12.8	"	4.2	4.1	"	"	"
921E	1823	11	6	8	45	17	30.6	29.0	s.purple	6.0	5.4	"	"	"
503B	1825	12	1	7	54	19	13.8	11.2	yellow	4.5	4.4	"	"	Medium
931B	1828	13	5	15	56	23	29.8	30.6	"	4.4	4.4	"	"	Good
549E	1829	14	41	12	34	14	32.8	46.8	s.purple	6.8	5.9	"	"	"
550A	1821	16	4	7	44	17	14.2	13.2	yellow	4.9	4.3	"	"	Medium
541B	1821	19	21	9	52	19	19.6	18.8	"	4.6	4.4	"	"	"
544A	1825	19	6	13	42	16	26.0	16.4	"	4.7	4.7	"	"	Good
922A	1822	21	16	15	52	19	33.8	34.8	"	5.7	5.5	"	"	"
543A	1828	24	2	10	37	14	15.4	19.2	"	5.2	4.4	"	"	Medium
920A	1823	26	18	18	42	16	25.6	32.0	"	5.3	4.9	"	"	Good

Table 1 (continued)

1820–1829

		No. Folds (M.I.T. ½ kg. T.)					Gr. Tear (Elmendorf)			pH (Cold Ext.)				
		Uninked		Inked										
No.	Year	C.P.	W.P.	C.P.	Basis Wt.	Easily Torn Cat.	C.P.	W.P.	Chlor. spot test	Un-inked	Inked	Rosin	Fiber (in %)	Length
546B	1824	27	27	24	52	19	24.6	34.2	yellow	4.6	4.5	N	100R	Good
907A	1829	29	22	25	54	19	26.8	25.6	"	5.5	5.3	"	"	"
935A	1826	39	21	32	48	19	39.0	39.8	"	5.3	5.3	"	"	"
904A	1828	45	17	34	53	19	31.4	19.0	"	4.8	4.7	"	"	Medium
912E	1822	52	64	28	37	14	26.8	30.0	"	5.4	5.3	"	"	Good
924A	1822	58	31	41	60	23	36.4	37.4	"	5.2	5.2	"	"	"
545A	1822	58	19	35	44	17	45.0	45.4	"	5.3	5.4	"	"	Medium
542A	1828	60	45	51	62	23	45.6	40.4	"	5.1	4.9	"	"	Good
906A	1826	60	22	29	44	17	40.0	35.2	s.purple	6.3	5.8	"	"	"
909A	1821	61	31	31	44	17	46.2	34.2	yellow	5.3	4.7	"	"	"
918A	1825	62	43	52	49	19	44.0	33.2	"	5.8	5.0	"	"	"
927A	1822	76	42	56	41	16	44.4	41.0	"	5.7	5.6	"	"	"
548E	1825	76	22	24	40	16	26.0	25.4	s.purple	6.0	6.1	"	"	"

Table 1 (continued)

1820–1829

		No. Folds (M.I.T. ½ kg. T.)					Gr. Tear (Elmendorf)			pH (Cold Ext.)				
		Uninked		Inked										
No.	Year	C.P.	W.P.	C.P.	Basis Wt.	Easily Torn Cat.	C.P.	W.P.	Chlor. spot test	Un-inked	Inked	Rosin	Fiber (in %)	Length
926A	1826	77	31	83	43	17	46.6	44.0	yellow	5.6	5.6	N	100R	Good
916A	1823	86	88	67	46	17	47.4	47.0	"	5.4	5.2	"	"	"
915A	1829	93	21	56	46	17	25.2	22.4	"	5.4	5.0	"	"	"
908A	1829	115	33	89	52	19	33.2	26.4	s.purple	7.4	7.0	"	"	"
929A	1825	132	37	51	46	17	39.2	30.8	yellow	5.6	5.1	"	"	"
901A	1829	153	70	179	36	14	42.6	37.6	purple	8.3	8.0	"	"	"
917A	1821	166	158	136	46	17	42.0	44.8	yellow	5.2	4.9	"	"	"
914A	1823	167	81	62	40	16	37.4	33.6	"	5.7	5.5	"	"	"
933A	1826	195	103	469	47	17	31.2	32.0	"	4.7	4.7	"	"	"
913A	1826	419	319	122	45	17	34.4	31.6	"	5.5	4.8	"	"	"
923A	1826	494	354	177	44	17	44.6	45.0	"	5.2	5.0	"	"	"
903A	1829	847	79	582	55	23	42.6	31.0	purple	7.1	6.7	"	"	"

Table 1 (continued)

1830–1839

		No. Folds (M.I.T. ½ kg. T.)					Gr. Tear (Elmendorf)			pH (Cold Ext.)				
		Uninked		Inked										
No.	Year	C.P.	W.P.	C.P.	Basis Wt.	Easily Torn Cat.	C.P.	W.P.	Chlor. spot test	Un-inked	Inked	Rosin	Fiber (in %)	Length
875A	1838	4	1	2	48	19	18.2	10.6	yellow	4.6	4.6	N	100R	Good
876A	1833	4	6	3	49	19	23.6	26.2	"	5.0	4.7	"	"	"
883A	1838	5	0	4	35	14	16.0	7.6	"	4.4	4.1	"	"	"
882A	1830	6	5	8	65	27	43.4	35.8	"	4.4	4.4	"	"	"
893A	1831	7	5	4	52	19	24.2	21.2	"	4.7	4.5	"	"	"
896A	1832	7	2	6	54	19	25.4	22.0	"	4.9	5.0	"	"	"
862A	1839	8	6	8	50	19	30.4	27.2	s.purple	6.4	6.2	"	"	"
899B	1833	10	1	14	56	23	23.2	29.4	yellow	4.5	4.6	P	"	"
898A	1832	10	12	8	38	16	17.0	18.4	"	5.5	5.0	N	"	"
887A	1833	11	14	9	44	17	30.8	23.0	"	5.3	5.3	"	"	Medium
886A	1839	11	9	16	41	16	28.6	35.6	s.purple	6.5	6.4	"	"	Good
884A	1836	16	13	17	46	17	24.4	24.8	yellow	5.7	5.6	"	"	"

Table 1 (continued)

1830-1839

		No. Folds (M.I.T. ½ kg. T.)					Gr. Tear (Elmendorf)			pH (Cold Ext.)				
		Uninked		Inked										
No.	Year	C.P.	W.P.	C.P.	Basis Wt.	Easily Torn Cat.	C.P.	W.P.	Chlor. spot test	Un-inked	Inked	Rosin	Fiber (in %)	Length
557A	1837	16	9	22	51	19	34.4	41.2	s.purple	6.6	6.6	N	100R	Good
865A	1834	16	16	9	46	17	20.4	39.0	" "	7.0	5.7	"	"	"
869B	1838	17	6	11	54	19	22.2	22.2	yellow	5.4	4.9	"	"	"
867A	1833	17	3	14	45	17	34.8	21.6	"	5.5	5.5	"	"	"
889A	1835	19	5	29	52	19	37.0	30.0	"	5.2	5.2	"	"	"
892A	1833	19	13	16	44	17	29.2	30.0	s.purple	6.5	6.2	"	"	"
868A	1831	20	8	12	52	19	30.0	22.8	yellow	4.7	4.7	"	"	Medium
895A	1839	21	14	20	47	17	29.0	32.8	purple	7.8	7.4	"	"	Good
553A	1831	28	32	19	41	16	20.0	23.6	yellow	5.2	5.1	"	"	Medium
554A	1834	31	66	28	47	17	23.2	49.8	purple	7.4	7.1	"	"	Good
871A	1831	34	31	44	49	19	32.0	33.8	yellow	5.1	5.4	"	"	"
861A	1838	34	29	21	34	14	32.0	33.6	s.purple	6.4	5.7	"	"	"
556A	1836	34	25	25	45	17	31.6	35.0	" "	6.5	6.7	"	"	Medium

Table 1 (continued)

1830–1839

No.	Year	No. Folds (M.I.T. ½ kg. T.)			Basis Wt.	Easily Torn Cat.	Gr. Tear (Elmendorf)		Chlor. spot test	pH (Cold Ext.)		Rosin	Fiber (in %)	Length
		Uninked		Inked										
		C.P.	W.P.	C.P.			C.P.	W.P.		Un-inked	Inked			
559B	1832	35	20	26	43	19	30.0	29.2	yellow	4.9	5.5	N	100R	Medium
881A	1839	37	14	27	51	19	28.0	29.6	"	5.1	5.1	"	"	Good
873A	1835	42	15	26	58	23	30.6	29.0	s.purple	6.0	5.9	"	"	"
551A	1832	51	19	59	49	19	43.4	39.4	" "	7.2	7.4	"	"	"
555A	1835	52	41	62	52	19	58.4	60.6	purple	8.0	7.6	"	"	"
863A	1837	56	53	54	43	17	36.8	34.8	"	6.8	6.5	"	"	"
878A	1834	57	25	46	46	17	42.0	39.6	"	7.1	6.9	"	"	"
864A	1834	66	81	46	48	19	41.8	52.0	"	7.8	7.7	"	"	"
900A	1836	67	51	64	52	19	41.8	39.2	s.purple	8.4	7.7	"	"	"
894A	1836	75	50	57	50	19	29.6	30.0	yellow	5.8	5.5	"	"	"
874A	1839	76	64	59	41	16	28.8	35.6	"	5.8	5.5	"	"	"
879E	1838	77	42	69	34	14	29.6	30.0	purple	7.7	7.8	"	"	"
891A	1833	80	59	60	58	23	45.0	43.6	"	7.2	6.8	"	"	"

Table 1 (continued)

1830-1839

		No. Folds (M.I.T. ½ kg. T.)				Easily	Gr. Tear (Elmendorf)		Chlor.	pH (Cold Ext.)				
		Uninked		Inked	Basis	Torn			spot	Un-				
No.	Year	C.P.	W.P.	C.P.	Wt.	Cat.	C.P.	W.P.	test	inked	Inked	Rosin	Fiber (in %)	Length
888A	1833	117	9	160	50	19	37.0	31.2	purple	8.2	7.6	N	100R	Good
890A	1838	121	120	74	42	16	30.0	28.8	yellow	5.5	5.3	"	"	"
877A	1832	125	76	103	52	19	51.8	45.2	s.purple	6.7	6.4	"	"	"
897B	1830	133	102	80	50	19	25.0	26.8	yellow	5.1	5.3	"	"	"
880A	1832	137	85	88	47	17	25.0	22.2	"	5.1	4.9	"	"	Medium
872A	1832	164	167	99	49	19	27.4	33.8	"	5.5	5.3	"	"	Good
870A	1835	174	215	153	45	17	28.0	28.4	s.purple	6.8	6.6	"	"	"
560A	1837	221	21	173	54	19	45.2	53.8	purple	7.2	7.3	"	"	Medium
552A	1830	321	59	177	42	16	32.0	23.2	yellow	5.3	5.2	"	"	Good
866A	1836	1230	510	1117	36	14	30.0	31.6	s.purple	7.0	6.5	"	"	Medium
558A	1832	1316	74	700	43	17	31.2	21.2	yellow	5.1	5.0	"	"	Good
885A	1836	1483	122	1052	48	19	39.2	27.4	purple	8.2	6.8	"	"	"

Table 1 (continued)

1840-1849

		No. Folds (M.I.T. ½ kg. T.)					Gr. Tear (Elmendorf)			pH (Cold Ext.)				
		Uninked		Inked	Basis	Easily Torn			Chlor. spot					
No.	Year	C.P.	W.P.	C.P.	Wt.	Cat.	C.P.	W.P.	test	Un-inked	Inked	Rosin	Fiber (in %)	Length
505A	1846	0	0	0	49	19	8.0	8.8	yellow	4.2	4.1	N	100R	Medium
842A	1844	3	1	2	37	14	15.8	14.8	"	4.8	4.8	"	"	Good
506B	1849	4	1	6	61	23	24.0	15.2	"	4.3	4.2	P	"	Medium
504A	1849	5	3	7	58	23	23.6	21.2	"	4.7	4.7	N	"	"
850A	1846	5	0	7	42	16	29.8	15.8	"	4.8	4.7	"	"	"
569A	1844	9	7	7	41	16	30.2	36.4	"	5.6	5.3	"	"	Good
852A	1840	9	12	10	44	17	30.2	38.0	s.purple	6.0	6.4	"	"	"
841A	1845	10	1	9	37	14	18.4	26.8	yellow	4.4	4.6	"	"	"
678A	1848	10	12	11	54	19	40.0	39.0	s.purple	6.0	5.9	"	"	Medium
561A	1846	11	2	3	53	19	25.4	20.0	yellow	4.9	4.4	"	"	Good
676A	1845	14	15	10	60	23	46.2	54.0	"	5.3	4.8	"	"	"
674B	1847	15	3	21	61	23	41.8	36.2	"	4.5	4.8	P	"	"

Table 1 (continued)

1840–1849

No.	Year	No. Folds (M.I.T. ½ kg. T.)			Basis Wt.	Easily Torn Cat.	Gr. Tear (Elmendorf)		Chlor. spot test	pH (Cold Ext.)		Rosin	Fiber (in %)	Length
		Uninked		Inked										
		C.P.	W.P.	C.P.			C.P.	W.P.		Un-inked	Inked			
563A	1845	15	7	16	61	23	39.6	36.0	yellow	5.0	4.8	P	100R	Medium
733A	1845	16	10	13	38	16	20.4	19.6	"	5.0	4.8	N	"	Good
848A	1849	19	10	16	53	19	42.4	35.4	"	5.2	4.8	"	"	"
739A	1846	20	13	15	48	19	31.8	28.2	"	5.3	5.3	"	"	"
567A	1842	21	21	17	47	17	24.8	26.8	"	5.8	5.3	"	"	"
849A	1846	21	29	19	49	19	32.8	30.2	"	5.8	5.6	"	"	"
570A	1844	23	18	17	54	19	45.6	50.8	"	6.2	5.7	"	"	"
857A	1848	24	35	21	47	17	25.6	25.6	"	4.9	4.7	"	"	"
846A	1847	26	5	10	52	19	19.8	16.8	"	4.6	4.3	"	"	"
562A	1849	29	45	34	47	17	34.4	50.0	s.purple	6.0	5.4	"	"	"
851A	1846	32	54	34	44	17	34.8	30.2	" "	6.3	6.1	"	"	"
844A	1848	34	42	25	63	23	53.0	66.0	yellow	5.4	5.1	"	"	"
858E	1845	34	15	36	48	19	25.8	26.0	s.purple	6.8	6.7	"	"	"

Table 1 (continued)

1840-1849

		No. Folds (M.I.T. ½ kg. T.)					Gr. Tear (Elmendorf)			pH (Cold Ext.)				
		Uninked		Inked										
No.	Year	C.P.	W.P.	C.P.	Basis Wt.	Easily Torn Cat.	C.P.	W.P.	Chlor. spot test	Un-inked	Inked	Rosin	Fiber (in %)	Length
854A	1843	36	29	28	44	17	31.4	35.6	yellow	5.1	4.8	N	100R	Good
731A	1842	38	27	33	44	17	41.2	38.4	purple	8.1	7.1	"	"	"
740A	1845	39	25	40	52	19	53.2	53.6	s.purple	6.2	6.0	"	"	"
859B	1840	41	34	45	54	19	28.4	24.8	yellow	4.8	4.7	P	"	"
735A	1846	43	28	22	51	19	36.6	44.2	"	5.4	5.3	N	"	"
680A	1848	43	24	20	63	23	54.8	57.0	s.purple	6.4	5.5	"	"	"
732A	1847	48	12	27	58	23	46.4	52.6	yellow	5.2	5.1	"	"	"
734A	1846	67	25	43	42	16	35.4	37.8	s.purple	6.5	6.1	"	"	"
845A	1841	69	27	37	47	17	27.0	24.4	yellow	6.2	5.8	"	"	"
677A	1842	70	15	40	47	17	30.0	30.8	"	5.0	4.8	"	"	"
564A	1847	72	46	66	53	19	47.4	47.2	purple	7.8	7.0	"	"	"
860B	1849	76	53	111	52	19	40.0	35.2	yellow	4.8	4.9	P	"	"
679A	1845	82	41	97	58	23	62.6	61.4	purple	7.8	6.5	N	"	Medium

Table 1 (continued)

1840–1849

		No. Folds (M.I.T. ½ kg. T.)					Gr. Tear (Elmendorf)			pH (Cold Ext.)				
		Uninked		Inked	Basis	Easily Torn			Chlor. spot	Un-				
No.	Year	C.P.	W.P.	C.P.	Wt.	Cat.	C.P.	W.P.	test	inked	Inked	Rosin	Fiber (in %)	Length
856A	1847	85	340	63	44	17	40.4	43.2	purple	7.5	6.3	N	100R	Good
736A	1847	90	24	22	54	19	42.0	42.6	yellow	5.0	4.6	"	"	"
566A	1848	92	13	33	58	23	26.8	23.8	"	4.9	4.6	"	"	"
568A	1844	93	99	49	46	17	36.8	44.8	"	5.8	5.2	"	"	"
737A	1848	105	6	27	58	23	46.0	36.4	"	4.9	4.8	"	"	"
738A	1847	185	137	175	55	23	45.4	46.2	"	5.4	4.7	"	"	"
847A	1848	204	102	121	49	19	55.0	63.2	purple	7.7	7.1	"	"	"
853A	1841	229	71	154	45	17	46.6	47.2	s.purple	7.2	6.8	"	"	"
855A	1847	232	124	123	48	19	42.4	38.6	yellow	5.0	4.7	"	"	"
843A	1841	261	7	109	35	14	30.4	21.6	purple	7.2	6.4	"	"	"
565A	1849	295	46	126	59	23	64.0	69.2	"	8.6	7.2	"	"	Medium
675A	1846	422	165	284	64	23	63.2	58.8	s.purple	6.1	5.9	"	"	Good

Table 1 (continued)

1850-1859

		No. Folds (M.I.T. ½ kg. T.)					Gr. Tear (Elmendorf)			pH (Cold Ext.)				
		Uninked		Inked										
No.	Year	C.P.	W.P.	C.P.	Basis Wt.	Easily Torn Cat.	C.P.	W.P.	Chlor. spot test	Un-inked	Inked	Rosin	Fiber (in %)	Length
516	1857	0	0	0	64	23	7.0	7.6	yellow	4.2	4.0	N	100R	Poor
839	1853	0	0	1	34	14	7.4	6.6	"	4.4	4.4	P	80R, 20HW	Good
513	1857	1	1	1	53	19	13.6	12.0	"	4.4	4.5	"	100R	"
829	1855	3	1	2	53	19	19.4	18.8	"	4.6	4.6	N	"	Medium
826	1859	3	4	3	53	19	22.4	24.4	"	4.8	4.7	P	50R, 50HW	"
576	1857	4	2	3	45	17	17.8	13.6	"	4.3	4.3	N	100R	Good
824	1852	4	4	4	62	23	28.0	25.4	"	4.9	4.8	"	"	"
577	1859	5	5	4	50	19	22.4	22.8	"	5.3	4.8	"	"	"
578	1855	7	4	4	46	17	22.0	19.6	"	4.7	4.6	"	"	Medium
823	1853	8	5	10	60	23	28.4	30.2	"	4.5	4.7	P	"	Good
580	1857	8	5	7	57	23	29.0	36.8	"	4.6	4.7	"	"	Medium
835	1856	9	12	14	60	23	38.6	38.4	"	4.6	4.7	"	"	Good

Table 1 (continued)

1850-1859

		No. Folds (M.I.T. ½ kg. T.)				Easily	Gr. Tear (Elmendorf)		Chlor.	pH (Cold Ext.)				
		Uninked		Inked	Basis	Torn			spot	Un-				
No.	Year	C.P.	W.P.	C.P.	Wt.	Cat.	C.P.	W.P.	test	inked	Inked	Rosin	Fiber (in %)	Length
821	1857	9	6	13	63	23	42.2	31.0	yellow	4.6	4.7	N	100R	Good
725	1858	9	4	7	51	19	21.4	28.8	"	4.9	4.7	"	"	"
836	1857	9	14	10	59	23	48.0	46.2	"	5.0	4.8	"	95R, 5HW	"
838	1857	10	8	17	59	23	33.8	34.0	"	4.4	4.6	P	100R	"
822	1857	10	11	10	38	16	12.8	14.4	"	4.6	4.3	"	"	"
837	1857	10	9	12	47	17	26.4	27.0	"	4.7	4.7	N	"	"
830	1855	10	14	15	41	16	17.4	21.2	"	5.1	4.9	"	"	"
834	1853	11	7	10	47	17	28.6	27.2	"	5.0	5.0	P	95R, 5S	"
575	1851	12	6	6	53	19	29.8	27.0	"	5.3	4.8	N	100R	"
572	1856	13	7	11	61	23	40.4	40.2	purple	8.0	7.9	"	"	"
722	1857	14	6	10	57	23	36.0	38.8	yellow	4.9	4.8	"	"	"
721	1856	14	3	3	39	16	23.2	20.0	"	5.4	4.8	"	"	"
514	1855	15	5	14	48	19	32.8	29.4	"	5.1	5.2	"	"	Medium

Table 1 (continued)

1850-1859

		No. Folds (M.I.T. ½ kg. T.)					Gr. Tear (Elmendorf)			pH (Cold Ext.)				
		Uninked		Inked										
No.	Year	C.P.	W.P.	C.P.	Basis Wt.	Easily Torn Cat.	C.P.	W.P.	Chlor. spot test	Un-inked	Inked	Rosin	Fiber (in %)	Length
665	1854	15	13	11	48	19	37.0	43.2	yellow	5.4	5.4	N	100R	Good
661	1857	17	9	12	49	19	35.2	31.2	"	5.2	5.1	P	"	"
664	1850	17	12	15	55	23	38.0	36.2	purple	7.0	6.7	N	"	"
831	1857	18	10	12	52	19	25.4	22.8	yellow	4.7	4.5	P	"	"
724	1852	20	11	18	62	23	35.2	36.8	"	5.1	4.8	N	"	"
840	1853	20	41	23	60	23	63.2	58.4	purple	7.7	8.0	P	"	"
579	1852	22	11	20	52	19	35.6	36.0	yellow	5.1	5.0	N	"	"
728	1857	24	11	18	54	19	38.8	43.6	s.purple	7.2	6.1	"	"	"
828	1859	25	11	29	54	19	36.8	41.2	yellow	5.1	5.5	P	"	"
723	1853	25	10	21	61	23	51.2	49.2	s.purple	7.0	6.7	N	"	"
571	1857	33	14	38	52	19	41.6	39.6	yellow	4.7	5.1	P	"	"
729	1855	34	8	18	52	19	26.4	34.2	"	4.8	4.6	"	"	"
666	1850	34	22	16	52	19	30.4	31.6	"	5.3	5.0	N	"	"

Table 1 (continued)

1850-1859

No.	Year	No. Folds (M.I.T. ½ kg. T.)			Basis Wt.	Easily Torn Cat.	Gr. Tear (Elmendorf)		Chlor. spot test	pH (Cold Ext.)		Rosin	Fiber (in %)	Length
		Uninked		Inked										
		C.P.	W.P.	C.P.			C.P.	W.P.		Un-inked	Inked			
573	1851	36	5	8	58	23	19.2	22.0	yellow	4.4	4.2	P	100R	Medium
726	1853	36	18	26	60	23	43.8	40.6	"	5.3	5.3	N	"	Good
833	1856	41	16	44	62	23	46.4	57.6	purple	6.4	6.5	"	"	"
515	1850	42	20	29	52	19	51.6	50.2	s.yellow	5.6	5.1	"	"	"
574	1854	42	19	29	54	19	61.4	61.0	s.purple	5.8	6.2	"	"	Medium
662	1857	49	7	47	91	--	97.6	91.2	yellow	5.4	6.8	"	"	Good
663	1859	73	30	32	53	19	53.2	47.6	purple	8.8	8.3	"	"	"
827	1851	81	41	56	47	17	33.2	35.2	"	7.2	7.3	"	"	"
727	1850	111	20	83	43	17	57.0	61.8	"	8.1	8.4	"	"	"
730	1851	128	27	81	45	17	43.2	37.4	s.purple	6.4	6.0	"	"	"
825	1858	130	39	82	40	16	30.0	27.6	" "	6.4	6.1	"	"	"
832	1853	308	115	255	48	19	42.2	46.0	purple	8.0	7.5	"	"	"

Table 1 (continued)

1860–1869

		No. Folds (M.I.T. ½ kg. T.)					Gr. Tear (Elmendorf)			pH (Cold Ext.)				
		Uninked		Inked										
No.	Year	C.P.	W.P.	C.P.	Basis Wt.	Easily Torn Cat.	C.P.	W.P.	Chlor. spot test	Un-inked	Inked	Rosin	Fiber (in %)	Length
509	1867	0	0	0	76	31	18.8	9.2	yellow	4.0	4.3	P	100R	Poor
652	1868	0	0	0	51	19	12.0	8.4	"	4.7	4.6	N	"	Good
817	1863	1	0	1	47	17	12.4	10.8	"	4.1	4.1	"	"	Medium
582	1860	1	1	1	56	23	16.0	11.2	"	4.4	4.5	P	50R, 25HW, 25SW	"
517	1867	1	2	2	57	23	18.4	19.8	"	4.4	4.4	N	100R	"
808	1864	1	1	0	37	14	5.2	5.0	"	4.6	4.3	"	60R, 30HW, 10SW	"
719	1866	1	2	4	72	27	28.0	22.4	"	5.1	4.9	P	100R	Good
816	1869	2	0	1	51	19	14.0	15.2	"	4.0	4.5	"	"	"
586	1865	2	1	1	60	23	20.0	20.0	"	4.6	4.3	N	"	"
713	1866	2	2	2	46	17	15.6	13.4	"	4.9	4.5	"	"	"
810	1864	3	2	1	59	23	23.2	13.4	"	4.5	4.3	"	"	"
806	1867	3	2	4	79	31	39.6	31.4	"	4.5	4.5	P	"	"

Table 1 (continued)

1860–1869

No.	Year	No. Folds (M.I.T. ½ kg. T.) Uninked C.P.	Uninked W.P.	Inked C.P.	Basis Wt.	Easily Torn Cat.	Gr. Tear (Elmendorf) C.P.	Gr. Tear (Elmendorf) W.P.	Chlor. spot test	pH (Cold Ext.) Un-inked	pH (Cold Ext.) Inked	Rosin	Fiber (in %)	Length
807	1864	3	1	2	63	23	19.6	20.4	yellow	4.6	4.4	N	100R	Good
718	1864	3	5	4	56	23	20.6	18.4	s.purple	6.1	6.0	P	60SW, 40HW	Medium
802	1862	4	4	10	42	16	14.0	16.0	yellow	4.4	4.5	"	100R	"
511	1863	4	3	3	71	27	18.6	21.2	"	4.4	4.6	"	"	"
653	1869	4	2	4	53	19	21.0	17.4	"	4.5	4.6	"	"	"
714	1868	4	3	4	47	17	20.6	18.0	"	4.8	4.7	N	"	Good
715	1868	4	3	3	48	19	20.0	18.2	"	5.1	5.2	P	"	"
581	1863	5	7	4	52	19	21.2	21.8	"	4.7	4.5	"	25R, 75HW	Poor
711	1865	6	2	8	37	14	19.2	17.8	"	4.6	4.7	N	100R	Good
588	1869	6	5	6	52	19	25.0	26.2	"	5.1	5.3	P	90R, 5CW, 5S	Medium
809	1865	7	1	5	49	19	16.0	17.2	"	4.4	4.4	"	100R	Good
654	1866	7	5	8	54	19	32.0	28.0	"	4.7	4.6	"	"	"
587	1867	8	7	5	61	23	30.6	34.0	"	5.5	5.2	"	90R, 5CW, 5S	Medium

Table 1 (continued)

1860–1869

		No. Folds (M.I.T. ½ kg. T.)					Gr. Tear (Elmendorf)			pH (Cold Ext.)				
		Uninked		Inked										
No.	Year	C.P.	W.P.	C.P.	Basis Wt.	Easily Torn Cat.	C.P.	W.P.	Chlor. spot test	Un-inked	Inked	Rosin	Fiber (in %)	Length
590	1866	8	7	7	67	27	33.8	49.6	yellow	5.8	5.4	N	100R	Good
804	1867	9	3	4	52	19	25.2	21.8	"	4.8	4.6	"	"	"
813	1865	9	8	9	50	19	22.2	22.0	"	4.9	4.9	"	60R, 20HW, 10SW, 10S	Medium
803	1866	10	2	26	74	27	39.0	42.2	"	4.5	5.3	P	100R	Good
716	1869	10	4	8	49	19	21.2	20.4	"	5.1	4.8	"	"	Medium
512	1860	11	4	7	74	27	54.0	49.6	"	5.0	5.2	"	"	"
518	1864	11	5	7	62	23	21.0	24.0	"	5.6	5.4	N	"	"
712	1869	12	7	10	64	23	31.4	27.0	"	4.6	4.7	P	"	"
655	1860	13	5	8	38	16	19.6	18.0	s.purple	6.3	6.4	N	"	Good
814	1869	14	11	12	51	19	22.2	25.2	yellow	5.0	5.1	P	20R, 60HW, 20SW	Poor
812	1861	14	28	16	54	19	34.4	36.0	"	5.3	5.4	N	100R	Good
819	1863	17	12	47	57	23	40.6	33.2	"	4.7	5.1	"	"	"
583	1868	18	10	7	47	17	15.2	13.8	"	4.5	4.5	P	"	"

Table 1 (continued)

1860–1869

		No. Folds (M.I.T. ½ kg. T.)					Gr. Tear (Elmendorf)			pH (Cold Ext.)				
		Uninked		Inked										
No.	Year	C.P.	W.P.	C.P.	Basis Wt.	Easily Torn Cat.	C.P.	W.P.	Chlor. spot test	Un-inked	Inked	Rosin	Fiber (in %)	Length
717	1868	19	6	9	43	17	19.0	14.4	yellow	5.0	4.7	N	100R	Good
811	1862	20	13	13	69	27	41.2	37.4	"	5.1	4.8	"	"	"
805	1869	28	9	28	46	17	26.2	20.6	"	4.6	4.5	"	"	"
818	1867	28	27	30	47	17	31.0	33.6	purple	8.0	8.3	"	"	"
651	1860	32	8	22	55	23	50.2	45.4	"	7.9	7.4	"	"	"
589	1868	37	18	22	49	19	30.8	36.0	s.purple	6.5	5.9	"	"	"
720	1868	45	20	28	54	19	34.4	26.6	purple	7.2	6.2	"	"	"
815	1860	60	34	51	40	16	50.2	45.0	"	7.9	7.2	"	"	"
585	1860	99	23	43	52	19	48.0	48.2	"	8.0	7.0	"	"	"
820	1860	109	129	154	46	17	41.2	29.0	"	8.1	7.6	"	"	"
801	1860	137	53	66	61	23	49.2	42.4	yellow	5.0	4.6	"	"	"
584	1868	215	63	157	56	23	40.0	37.4	"	5.7	5.4	"	"	"

Table 1 (continued)

1870-1879

		No. Folds (M.I.T. ½ kg. T.) Uninked		No. Folds (M.I.T. ½ kg. T.) Inked		Easily Torn	Gr. Tear (Elmendorf)		Chlor. spot	pH (Cold Ext.)				
No.	Year	C.P.	W.P.	C.P.	Basis Wt.	Cat.	C.P.	W.P.	test	Un-inked	Inked	Rosin	Fiber (in %)	Length
796	1870	0	0	4	41	16	14.8	15.0	yellow	3.9	4.2	?	60R, 40GW	Medium
710	1870	0	0	1	76	31	17.6	14.4	"	3.9	4.4	?	80GW, 20CW	Poor
507	1874	0	0	0	60	23	10.0	8.0	"	4.2	4.2	P	100R	"
510	1879	0	0	1	98	—	30.0	21.6	"	4.2	4.5	"	90R, 10S	"
704	1877	0	1	0	62	23	18.6	12.8	"	4.5	4.3	"	20R, 80HW& SW	"
508	1872	1	0	4	54	19	14.0	9.8	"	4.1	4.3	"	90R, 10S	Medium
646	1872	1	1	1	51	19	14.8	10.8	"	4.3	4.4	"	40SW, 40HW, 20S	Poor
592	1873	1	1	0	55	23	9.6	10.2	"	4.3	4.2	"	20R, 50HW, 30SW	"
591	1879	1	1	1	60	23	14.2	14.8	"	4.4	4.3	"	60HW, 40SW	"
788	1874	1	2	1	40	16	9.8	8.4	"	4.5	4.5	"	30R, 40SW, 30HW	Good
643	1875	1	1	1	73	27	22.6	18.0	"	4.5	4.5	"	60SW, 40HW	Medium
782	1875	1	1	2	84	31	27.6	25.0	"	4.5	4.6	"	100R	"

Table 1 (continued)

1870–1879

		No. Folds (M.I.T. ½ kg. T.)					Gr. Tear (Elmendorf)			pH (Cold Ext.)				
		Uninked		Inked										
No.	Year	C.P.	W.P.	C.P.	Basis Wt.	Easily Torn Cat.	C.P.	W.P.	Chlor. spot test	Un-inked	Inked	Rosin	Fiber (in %)	Length
705	1875	1	2	1	52	19	13.4	13.2	yellow	4.7	4.7	P	70HW, 30SW	Medium
702	1872	1	1	1	56	23	17.2	14.4	"	4.9	4.7	"	65HW, 25S, 10SW	Poor
783	1873	2	1	4	91	—	27.8	30.8	"	4.4	4.5	"	100R	Good
786	1875	2	1	1	62	23	12.6	10.4	"	4.4	4.2	"	60R, 20SW, 20HW	"
794	1871	2	3	2	38	16	10.8	8.8	"	4.5	4.4	"	100R	"
645	1872	2	2	0	59	23	14.4	12.6	"	4.5	4.3	"	50SW, 30HW, 20S	Poor
641	1875	2	3	3	93	—	44.4	35.6	"	4.5	4.5	"	60HW, 20SW, 20S	"
707	1879	2	2	3	51	19	20.8	15.0	"	4.8	4.8	"	60SW, 30HW, 10S	Medium
644	1870	2	2	2	44	17	10.8	9.8	"	4.9	4.9	"	60SW, 20S, 20HW	"
791	1879	3	3	4	64	23	22.0	20.4	"	4.5	4.6	"	75R, 15HW, 10SW	Good
797	1873	3	1	6	48	19	13.6	19.2	"	4.6	4.6	"	90R, 10SW	"
642	1879	3	2	3	77	31	31.8	32.0	"	4.6	4.7	"	90SW, 10HW	"
594	1872	3	1	4	61	23	21.8	20.8	"	4.7	4.7	"	30R, 30S, 20HW, 20SW	Poor

Table 1 (continued)

1870-1879

		No. Folds (M.I.T. ½ kg. T.)					Gr. Tear (Elmendorf)			pH (Cold Ext.)				
		Uninked		Inked										
No.	Year	C.P.	W.P.	C.P.	Basis Wt.	Easily Torn Cat.	C.P.	W.P.	Chlor. spot test	Un-inked	Inked	Rosin	Fiber (in %)	Length
593	1876	3	1	3	47	17	14.2	14.4	yellow	4.7	4.7	P	80R, 20SW	Good
781	1873	4	2	4	55	23	21.0	22.2	"	4.9	4.9	"	10R, 70HW, 10SW, 10S	Poor
647	1872	4	1	10	71	27	21.8	26.8	"	4.3	4.6	"	50SW, 30HW, 20S	"
792	1879	4	2	3	44	17	13.4	10.0	"	4.3	4.3	"	60R, 30HW, 10SW	Medium
701	1872	4	2	2	70	27	17.8	15.2	"	4.5	4.4	"	70SW, 30HW	"
793	1873	4	4	5	82	31	33.0	32.0	"	4.5	4.6	"	100R	Good
596	1877	4	2	7	46	17	19.6	16.0	"	4.9	4.9	"	20R, 50SW, 20HW, 10S	Poor
784	1874	5	3	10	64	23	24.4	31.2	"	4.4	4.4	"	100R	Good
706	1878	5	6	3	58	23	16.6	17.0	"	4.5	4.5	N	60HW, 30SW, 10S	Poor
598	1877	5	4	2	57	23	18.8	14.0	"	4.7	4.6	P	20R, 60HW, 20SW	"
708	1873	5	3	2	42	16	14.4	11.8	"	4.8	4.6	"	80SW, 10S, 10HW	Medium
599	1870	5	4	4	47	17	23.6	18.4	"	5.1	4.9	N	80R, 20HW	Good
799	1873	6	3	5	42	16	13.6	12.2	"	4.5	4.5	P	100R	"

Table 1 (continued)

1870-1879

		No. Folds (M.I.T. ½ kg. T.)					Gr. Tear (Elmendorf)			pH (Cold Ext.)				
		Uninked		Inked										
No.	Year	C.P.	W.P.	C.P.	Basis Wt.	Easily Torn Cat.	C.P.	W.P.	Chlor. spot test	Un-inked	Inked	Rosin	Fiber (in %)	Length
800	1872	6	6	5	51	19	18.6	22.4	yellow	4.6	4.6	P	100R	Good
787	1874	7	8	5	51	19	16.4	15.6	"	4.4	4.3	"	70R, 20HW, 10SW	"
785	1871	7	3	9	60	23	23.4	22.0	"	4.6	4.7	"	80R, 20SW	"
795	1879	7	5	5	52	19	14.4	16.2	"	4.7	4.7	"	50R, 50HW	Medium
709	1876	11	5	8	36	14	14.0	13.2	"	4.6	4.5	"	70SW, 20S, 10HW	Good
595	1871	14	6	11	61	23	33.2	23.2	"	4.6	4.7	"	100R	"
600	1871	17	9	18	47	17	21.6	25.2	"	4.9	5.3	"	75R, 25SW	Medium
789	1877	17	34	15	90	—	40.8	41.2	"	4.9	4.8	"	75R, 20HW, 5SW	"
798	1873	22	6	26	53	19	33.4	33.6	"	5.3	5.5	"	50R, 40S, 5SW, 5HW	"
703	1879	36	16	22	64	23	41.2	36.6	"	5.5	5.4	"	100R	"
597	1871	89	37	75	45	17	29.2	30.4	"	5.6	5.8	"	55R, 35SW, 10HW	Good
790	1873	144	96	248	54	19	39.8	34.2	"	5.3	5.5	N	70S, 20SW, 10HW	Poor

Table 1 (continued)

1880-1889

No.	Year	No. Folds (M.I.T. ½ kg. T.) Uninked C.P.	No. Folds (M.I.T. ½ kg. T.) Uninked W.P.	No. Folds (M.I.T. ½ kg. T.) Inked C.P.	Basis Wt.	Easily Torn Cat.	Gr. Tear (Elmendorf) C.P.	Gr. Tear (Elmendorf) W.P.	Chlor. spot test	pH (Cold Ext.) Un-inked	pH (Cold Ext.) Inked	Rosin	Fiber (in %)	Length
780	1886	0	0	0	46	17	8.4	10.0	yellow	3.8	3.8	?	60GW, 40SW	Poor
634	1882	0	0	0	63	23	11.0	8.0	"	4.3	4.3	P	80HW, 20SW	"
770	1884	0	0	0	85	—	13.0	10.6	"	4.3	4.1	N	10R, 50HW, 20SW, 20S	"
632	1881	0	0	0	62	23	12.6	10.8	"	4.4	4.4	P	60HW, 30S, 10SW	"
772	1883	0	1	1	65	27	15.0	12.8	"	4.4	4.3	"	30R, 40HW, 30SW	Good
603	1882	0	1	1	57	23	14.8	15.4	"	4.6	4.6	"	60HW, 40SW	Medium
606	1887	0	1	1	72	27	22.4	22.4	"	4.6	4.8	"	60HW, 20SW, 20S	"
631	1887	1	1	1	33	14	6.6	4.8	"	3.8	3.7	?	70GW, 30SW	Poor
769	1884	1	0	0	77	31	19.6	15.2	"	4.2	4.2	P	30R, 50HW, 20SW	Medium
762	1888	1	0	0	73	27	20.8	15.6	"	4.2	4.2	"	30R, 50HW, 20SW	Good
640	1884	1	0	0	57	23	10.2	10.8	"	4.4	4.3	"	70HW, 30SW	Medium
609	1887	1	0	0	76	31	17.8	13.0	"	4.4	4.3	"	80S, 10SW, 10HW	Poor

Table 1 (continued)

1880-1889

		No. Folds (M.I.T. ½ kg. T.)					Gr. Tear (Elmendorf)			pH (Cold Ext.)				
		Uninked		Inked										
No.	Year	C.P.	W.P.	C.P.	Basis Wt.	Easily Torn Cat.	C.P.	W.P.	Chlor. spot test	Un-Inked	Inked	Rosin	Fiber (in %)	Length
765	1884	1	2	1	75	31	21.0	17.8	yellow	4.5	4.4	P	25R, 45HW, 30SW	Good
636	1888	1	1	0	79	31	17.6	20.6	"	4.7	4.7	"	80HW, 20SW	Poor
604	1886	1	1	2	78	31	25.0	25.4	"	4.8	5.0	"	55HW, 45SW	Good
775	1887	1	1	0	82	31	17.2	20.2	"	4.8	4.7	"	50R, 30HW, 20SW	"
695	1883	1	1	0	60	23	13.2	12.0	"	4.9	4.4	"	60HW, 40SW	Medium
635	1886	1	1	2	74	27	19.4	24.2	"	4.9	4.9	"	80HW, 20SW	Poor
773	1880	2	2	2	36	14	9.8	11.4	"	4.5	4.3	"	30R, 40HW, 30SW	Good
601	1884	2	1	2	71	27	32.4	24.8	"	4.5	4.6	"	50SW, 50HW	"
764	1885	2	1	2	69	27	13.0	17.4	"	4.5	4.5	"	60HW, 40SW	Medium
766	1888	2	2	5	60	23	26.4	27.2	"	4.5	4.6	N	70HW, 30SW	"
767	1886	2	3	1	80	31	40.6	34.0	"	4.6	4.6	P	30R, 50HW, 20SW	"
696	1887	2	3	2	54	19	19.0	18.8	"	4.6	4.7	"	60HW, 20SW, 20GW	"
698	1886	2	5	3	64	23	27.4	23.2	"	4.7	4.7	"	70HW, 30SW	"

Table 1 (continued)

1880–1889

No.	Year	No. Folds (M.I.T. ½ kg. T.) Uninked C.P.		Inked C.P.	Basis Wt.	Easily Torn Cat.	Gr. Tear (Elmendorf) C.P.	W.P.	Chlor. spot test	pH (Cold Ext.) Un-inked	Inked	Rosin	Fiber (in %)	Length
		C.P.	W.P.	C.P.										
637	1886	2	1	2	77	31	21.8	26.6	yellow	4.9	5.1	P	60HW, 30SW, 10S	Poor
778	1886	3	6	3	55	23	17.6	15.0	"	4.6	4.6	"	10R, 50HW, 40SW	Good
607	1881	3	3	4	43	17	15.2	13.6	"	4.7	4.7	"	50SW, 50HW	Medium
697	1887	3	1	2	51	19	12.0	13.0	"	4.9	4.5	"	60HW, 40SW	"
774	1885	4	2	4	76	31	23.2	32.4	"	4.5	4.4	"	40R, 30SW, 30HW	"
763	1888	4	3	3	83	31	37.4	36.0	"	4.6	4.5	"	10R, 70HW, 20SW	"
606	1888	4	2	3	70	27	28.4	29.6	"	4.7	4.6	"	10R, 50HW, 40SW	Good
638	1889	4	5	2	39	16	12.8	13.0	"	4.8	4.3	"	20R, 60SW, 20HW	"
776	1889	4	1	3	73	27	24.4	25.4	"	4.9	4.9	"	30R, 50HW, 20SW	Medium
768	1885	4	2	4	76	31	31.8	30.8	"	5.5	5.5	"	30R, 50HW, 20SW	Good
777	1882	5	4	5	54	19	15.6	19.8	"	4.6	4.5	"	50R, 25SW, 25HW	"
610	1883	5	3	6	79	31	39.6	30.6	"	4.6	5.0	"	60SW, 40HW	Medium
779	1889	5	5	4	52	19	21.2	16.4	"	5.0	4.9	"	50R, 30HW, 20SW	Good

Table 1 (continued)

1880–1889

		No. Folds (M.I.T. ½ kg. T.)					Gr. Tear (Elmendorf)			pH (Cold Ext.)				
		Uninked		Inked										
No.	Year	C.P.	W.P.	C.P.	Basis Wt.	Easily Torn Cat.	C.P.	W.P.	Chlor. spot test	Un-inked	Inked	Rosin	Fiber (in %)	Length
691	1886	5	2	3	61	23	26.6	19.8	yellow	5.1	4.9	P	80HW, 20SW	Poor
699	1881	6	7	8	58	23	30.2	32.8	"	5.3	5.2	"	10R, 60HW, 30SW	Medium
605	1880	7	2	6	30	12	10.4	9.0	"	4.5	4.6	"	50SW, 30HW, 20S	"
602	1882	7	4	9	58	23	24.8	25.4	"	4.7	4.9	"	60HW, 20SW, 20S	Poor
693	1887	7	4	8	39	16	14.8	13.6	"	5.2	5.1	"	60HW, 40SW	Medium
633	1881	7	10	9	60	23	28.8	29.8	"	5.4	5.3	"	50SW, 50HW	Good
700	1889	8	3	7	49	19	15.2	18.0	"	4.5	4.6	"	50SW, 50HW	"
694	1888	8	4	9	59	23	23.6	23.8	"	4.9	4.9	"	70HW, 20SW, 10S	Poor
692	1889	8	8	7	75	31	34.6	42.4	s.purple	6.5	7.0	"	50HW, 30S, 20SW	"
639	1888	11	4	10	66	27	34.2	28.2	yellow	4.8	5.1	"	70HW, 30SW	"
761	1881	17	6	28	34	14	13.0	11.6	"	4.4	4.5	"	60HW, 40SW	"
771	1887	21	25	19	62	23	30.8	26.8	"	5.5	5.4	"	20R, 60HW, 10SW, 10GW	Medium

Table 1 (continued)

1890-1899

		No. Folds (M.I.T. ½ kg. T.)					Gr. Tear (Elmendorf)			pH (Cold Ext.)				
		Uninked		Inked										
No.	Year	C.P.	W.P.	C.P.	Basis Wt.	Easily Torn Cat.	C.P.	W.P.	Chlor. spot test	Un-inked	Inked	Rosin	Fiber (in %)	Length
755	1895	0	0	1	60	23	16.0	15.0	yellow	4.3	4.3	P	30R, 50HW, 20SW	Good
520	1895	0	1	1	67	27	16.4	16.8	"	4.3	4.3	"	90S, 10HW	Poor
615	1896	0	1	1	77	31	17.0	16.8	"	4.3	4.5	"	5R, 65HW, 30SW	Medium
750	1897	0	1	0	93	—	22.2	20.8	"	4.4	4.4	"	30R, 40HW, 30SW	Good
623	1891	0	1	1	78	31	19.2	22.6	"	4.7	4.9	"	30R, 40SW, 30HW	Medium
684	1899	0	0	0	78	31	12.0	14.4	"	4.7	4.5	"	10R, 60HW, 30SW	"
627	1895	0	1	0	117	—	20.6	25.0	"	4.8	4.4	"	80HW, 20SW	Poor
753	1891	1	0	0	46	17	11.8	10.2	"	4.1	4.1	"	20R, 60HW, 20SW	Medium
741	1892	1	0	1	76	31	18.2	20.8	"	4.1	4.3	?	40GW, 40HW, 20SW	Poor
754	1895	1	0	0	82	31	16.8	12.2	"	4.1	4.3	P	60HW, 40SW	Medium
611	1894	1	0	1	75	31	20.4	20.2	"	4.2	4.4	"	70HW, 30SW	Poor
749	1893	1	0	1	43	17	10.2	12.6	"	4.3	4.4	"	80HW, 20SW	"

Table 1 (continued)

1890-1899

		No. Folds (M.I.T. ½ kg. T.)					Gr. Tear (Elmendorf)			pH (Cold Ext.)				
		Uninked		Inked										
No.	Year	C.P.	W.P.	C.P.	Basis Wt.	Easily Torn Cat.	C.P.	W.P.	Chlor. spot test	Un-inked	Inked	Rosin	Fiber (in %)	Length
748	1895	1	1	0	83	31	24.0	20.0	yellow	4.3	4.3	P	10R, 70HW, 20SW	Medium
757	1898	1	1	1	84	31	23.6	24.0	"	4.3	4.3	"	5R, 55HW, 30SW, 10S	"
751	1899	1	1	0	69	27	18.4	19.0	"	4.3	4.5	"	20R, 40SW, 40HW	Good
744	1898	1	3	1	62	23	14.6	12.4	"	4.4	4.3	"	5R, 55HW, 40SW	Medium
619	1890	1	1	1	47	17	14.2	11.2	"	4.5	4.4	"	70S, 20HW, 10SW	Poor
626	1893	1	1	1	75	31	19.0	21.8	"	4.5	4.4	"	60HW, 40SW	Medium
614	1893	1	1	1	78	31	17.8	18.6	"	4.6	4.5	"	85HW, 15SW	Poor
682	1892	1	1	2	60	23	14.0	14.4	"	4.7	4.6	"	10R, 60HW, 30SW	Medium
613	1896	1	1	1	93	—	26.2	24.2	"	4.7	4.6	"	70HW, 30SW	"
752	1896	1	1	1	75	31	31.6	23.6	"	4.7	4.7	"	10R, 45SW, 45HW	Good
688	1897	1	2	1	66	27	24.8	18.4	"	4.7	4.3	"	25R, 55HW, 20SW	"
622	1898	1	1	1	63	23	22.8	21.8	"	4.8	4.5	N	35R, 65SW	"
759	1896	2	0	2	52	19	14.0	14.8	"	4.4	4.4	P	40S, 40SW, 20HW	Poor

Table 1 (continued)

1890-1899

		No. Folds (M.I.T. ½ kg. T.)					Gr. Tear (Elmendorf)			pH (Cold Ext.)				
		Uninked		Inked										
No.	Year	C.P.	W.P.	C.P.	Basis Wt.	Easily Torn Cat.	C.P.	W.P.	Chlor. spot test	Un-inked	Inked	Rosin	Fiber (in %)	Length
618	1891	2	2	2	61	23	22.0	19.2	yellow	4.5	4.3	P	30R, 40HW, 30SW	Medium
756	1899	2	5	2	51	19	15.6	13.2	"	4.5	4.5	"	10R, 40SW, 30HW, 20S	"
620	1897	2	4	2	64	23	16.6	18.2	"	4.6	4.6	"	10R, 50HW, 30SW, 10S	Poor
742	1898	2	1	1	78	31	27.2	27.8	"	4.8	4.8	"	10R, 50HW, 30SW, 10S	Medium
743	1898	2	2	2	86	—	29.0	22.8	"	5.2	5.5	"	5R, 55HW, 40SW	"
758	1890	2	1	1	84	31	40.2	34.2	"	5.3	5.7	"	10R, 50HW, 30SW, 10S	"
689	1898	2	1	2	82	31	30.0	31.6	"	5.4	5.2	"	50R, 30HW, 20SW	Good
747	1899	3	1	3	60	23	15.2	16.0	"	4.5	4.4	"	10R, 70HW, 20SW	Medium
686	1898	3	5	2	72	27	30.8	33.4	"	5.0	5.0	"	70HW, 30SW	"
746	1890	4	3	4	59	23	14.8	12.8	"	4.4	4.4	"	10R, 70HW, 20SW	"
625	1891	4	6	4	61	23	25.6	24.2	"	4.5	4.5	"	20R, 70HW, 10SW	"
685	1898	4	5	4	50	19	16.6	14.6	"	4.6	4.6	"	5R, 70HW, 25SW	Poor
683	1894	4	5	4	82	31	33.8	35.2	"	4.8	4.6	"	10R, 50HW, 40SW	Good

Table 1 (continued)

1890–1899

No.	Year	No. Folds (M.I.T. ½ kg. T.) Uninked C.P.	No. Folds (M.I.T. ½ kg. T.) Uninked W.P.	No. Folds (M.I.T. ½ kg. T.) Inked C.P.	Basis Wt.	Easily Torn Cat.	Gr. Tear (Elmendorf) C.P.	Gr. Tear (Elmendorf) W.P.	Chlor. spot test	pH (Cold Ext.) Un-inked	pH (Cold Ext.) Inked	Rosin	Fiber (in %)	Length
624	1898	4	5	4	70	27	42.8	31.4	yellow	4.8	4.6	P	20R, 45SW, 35HW	Good
687	1891	4	20	7	70	27	26.0	28.0	"	5.4	5.6	"	10R, 70HW, 20SW	Poor
612	1899	4	7	5	79	31	26.4	37.2	"	5.7	5.7	"	25R, 65HW, 10SW	Medium
628	1899	5	1	6	67	27	25.2	25.2	"	4.4	4.5	"	60HW, 40SW	"
681	1890	5	5	4	54	19	25.6	25.2	"	4.6	4.5	"	20R, 60HW, 20SW	"
616	1890	9	8	9	45	17	20.0	20.2	"	5.6	5.8	"	45HW, 30SW, 25S	Poor
690	1890	10	27	13	58	23	21.2	20.8	"	6.0	5.9	"	30R, 50HW, 20SW	Good
617	1891	11	12	34	65	27	47.2	42.8	"	5.5	5.8	"	10R, 45S, 25HW, 20SW	Poor
621	1893	12	19	22	39	16	20.2	17.6	"	5.7	5.5	?	60HW, 20GW, 20SW	Medium
760	1898	14	10	12	74	27	38.4	32.6	purple	7.2	7.4	P	60SW, 30S, 10HW	Poor
519	1892	15	13	27	72	27	58.4	46.0	yellow	5.8	5.8	?	50SW, 35HW, 15GW	Medium
745	1899	16	6	14	92	—	37.2	42.4	"	5.1	5.1	P	60HW, 40SW	Good

Table 2

The median C.P. folding endurance and tear resistance values for the first 25 books of each decade and the median values after testing 50 books per decade. The range of values for each test per decade is included.

Decade	No. Folds – C.P.		Fold range of 50 volumes	Tear Resistance – C.P.		Tear range of 50 volumes
	Median–1st 25 volumes	Median of 50 volumes		Median–1st 25 volumes	Median of 50 volumes	
1800–09	14	18	1 – 750	28.8	28.7	9.8 – 59.4
1810–19	21	22	1 – 433	22.6	23.6	11.4 – 40.8
1820–29	24	27	1 – 847	26.0	30.2	7.4 – 47.4
1830–39	35	35	4 – 1483	30.6	30.0	16.0 – 58.4
1840–49	29	35	0 – 422	36.8	36.0	8.0 – 64.0
1850–59	15	15	0 – 308	33.6	33.4	7.0 – 97.6
1860–69	6	8	0 – 215	21.0	22.2	5.2 – 54.0
1870–79	2	3	0 – 144	18.8	18.6	9.6 – 44.4
1880–89	2	2	0 – 21	19.4	19.5	6.6 – 40.6
1890–99	2	2	0 – 16	20.4	20.9	10.2 – 58.4

Table 3

The median number of folds (M.I.T. ½ kg. tension), tested in the direction of cross printing and with printing (uninked), tear resistance (inked), pH (uninked), percent samples with rosin and percent all rag, all chemical wood, mixture of fibers and percentage of various fiber lengths in each decade.

	No. Folds Uninked Area		Tear		pH uninked		Fiber			Fiber Length		
Decade	C.P.	W.P.	C.P.	W.P.	(cold ext.)	% papers with rosin	% Rag	% Mixture	% C.W.	% Good	% Medium	% Poor
1800-09	18	14	28.7	29.6	4.6	0	100	-	-	96	4	-
1810-19	22	15	23.6	25.4	4.7	0	100	-	-	94	6	-
1820-29	27	20	30.2	29.5	5.2	0	100	-	-	82	16	2
1830-39	35	21	30.0	30.0	5.8	2	100	-	-	84	16	-
1840-49	35	23	36.0	36.3	5.4	10	100	-	-	84	16	-
1850-59	15	10	33.4	34.1	5.1	32	92	8	-	84	14	2
1860-69	8	5	22.2	21.8	4.9	42	84	14	2	64	30	6
1870-79	3	2	18.6	16.6	4.5	94	20	70	10	36	30	34
1880-89	2	2	19.5	19.3	4.6	98	0	60	40	30	40	30
1890-99	2	1	20.9	20.8	4.6	98	0	80	20	22	50	28

Table 4

The number and percentage of papers falling in four different categories with pH 6.0 and above and pH 5.9 and below for the three groups of the period 1800-1899.

	pH 6.0 and above			
	51 folds or more	10-50 folds	2-9 folds	0-1 folds
First Group (250 books) 1800-1849	32 (13%)	20 (8%)	3 (1%)	0 (0%)
Second Group (100 books) 1850-1869	9 (9%)	11 (11%)	1 (1%)	0 (0%)
Third Group (150 books) 1870-1899	0 (0%)	2 (1%)	1 (1%)	0 (0%)
	Below pH 6.0			
First Group (250 books) 1800-1849	55 (22%)	90 (36%)	45 (18%)	5 (2%)
Second Group (100 books) 1850-1869	2 (2%)	35 (35%)	32 (32%)	10 (10%)
Third Group (150 books) 1870-1899	2 (1%)	13 (9%)	76 (51%)	56 (37%)

0-1 fold – Restoration Category

2-9 folds – Below Newsprint Category

10-50 folds – Newsprint Category

Table 5

The number of C.P. folds, pH, year made, % Chlorides and % Sulphates of 10 of the weakest papers and 10 of the strongest papers 1801-1837.

Ten old book papers (1801-1824) with lowest folds and pH

Sample Number	Uninked pH	C.P. Folds Uninked	Year	% Cl-	$\% SO_4^=$ on sheet wt.
671A	4.1	2	1801	.018	.371
667B	4.3	1	1801	.088	.120
994A	4.4	2	1801	.010	.238
657B	4.2	2	1807	.248	.323
630A	4.2	1	1808	.007	.324
911A	4.2	2	1820	.010	.384
502B	4.2	2	1821	.100	5.00
501A	4.2	1	1821	.018	.153
934A	4.0	2	1822	.000	.345
905A	4.5	3	1824	.004	.159

Ten old book papers (1802-1837) with highest folds and pH

670A	5.9	211	1802	.058	.493
656E	7.1	116	1805	.032	.286
995E	6.0	323	1808	.026	.318
964A	6.5	433	1818	.103	.002
914A	5.7	167	1823	.040	.054
913A	5.5	419	1826	.000	.003
903A	7.1	847	1829	.027	.085
901A	8.3	153	1829	.041	.018
866A	7.0	1230	1836	.051	.187
560A	7.2	221	1837	.042	.002

Table 6

The percentage of papers with alum rosin sizing, median values of folding strength C.P. in uninked area and pH (cold extraction) of all-rag, part-rag and no-rag papers by decade, 1850-1899.

	All-rag				Part-rag				No-rag			
Decade	No. Samples	% With Rosin	No. Folds	pH	No. Samples	% With Rosin	No. Folds	pH	No. Samples	% With Rosin	No. Folds	pH
1850-59	46	28	17	5.1	4	75	6	4.9	—	—	—	—
1860-69	42	36	10	4.8	7	71	6	4.9	1	—	—	—
1870-79	10	100	5	4.5	23	91	4	4.6	17	82	2	4.5
1880-89	—	—	—	—	19	95	4	4.6	31	90	2	4.6
1890-99	—	—	—	—	32	97	2	4.7	18	83	1	4.6

Table 7

The median pH, C.P. folds, and C.P. tear for the papers 1850-1859 sized with alum rosin and conventional type sizing and the same for the period 1860-1869 of the 100% rag papers and part rag papers.

	100% Rag			
	1850-59 Sized with		1860-69 Sized with	
	Rosin	Other	Rosin	Other
No. Samples	13	33	15	27
Median pH	4.6	5.3	4.5	5.0
Median C.P. Folds	17	17	4	14
Median C.P. Tear	29.0	35.2	21.2	26.2
	Part Rag			
No. Samples	3	1	5	2
Median pH	4.8	5.0	5.1	4.8
Median C.P. Folds	3	9	6	5
Median C.P. Tear	22.4	48.0	22.2	13.7

Table 8

Number of samples and folds, the pH (cold extraction) and percent of samples with good fiber length of papers 1800-1899 sized with alum rosin and glue.

		Alum Rosin Sized				Tub Sizing (glue)			
Decade	Rag Content	No. Samples	No. Folds	pH	% Good Fiber Length	No. Samples	No. Folds	pH	% Good Fiber Length
1800-09	All rag	—	—	—	—	50	18	4.6	96
1810-19	All rag	—	—	—	—	50	22	4.7	94
1820-29	All rag	—	—	—	—	50	27	5.2	82
1830-39	All rag	—	—	—	—	49	35	5.8	84
1840-49	All rag	—	—	—	—	45	36	5.6	87
1850-59	All rag	13	17	4.6	85	33	17	5.3	88
1860-69	All rag	15	4	4.5	53	27	14	5.0	89
1870-79	All rag	10	5	4.5	70	—	—	—	--
	Part rag	21	4	4.6	38	—	—	—	—
	No rag	14	2	4.6	14	—	—	—	—
1880-89	Part rag	18	4	4.6	67	—	—	—	--
	No rag	28	2	4.7	14	—	—	—	—
1890-99	Part rag	31	2	4.6	29	—	—	—	--
	No rag	15	1	4.5	7	—	—	—	—

Table 9

The average number of folds, average pH (cold extraction) and fiber content of the three strongest of the least acid papers of each decade, 1800-1899.

	Three Strongest from the Least Acid			
Decade	Sample Numbers	Ave. No. Folds	Ave. pH	Fiber Content
1800-09	995E, 670A, 656E	217	6.1	Rag
1810-19	964A, 537A, 973A	218	5.5	Rag
1820-29	903A, 901A, 908A	372	7.9	Rag
1830-39	885A, 866A, 560A	978	7.7	Rag
1840-49	843A, 565A, 675A	326	8.0	Rag
1850-59	730, 825, 832	189	7.3	Rag
1860-69	820, 585, 815	89	8.0	Rag
1870-79	703, 597, 790	90	5.5	R, S, SW, HW
1880-89	633, 692, 771	12	5.6	R, HW, SW, S, GW
1890-99	760, 690, 519	13	6.1	R, HW, SW, S, GW

Table 10

The number of folds (C.P. uninked), grams tear (C.P. inked), pH (uninked) and fiber analysis of 35 book papers 1870-1899 alum rosin sized and composed of 100% chemical wood fibers. Averages are included for the test values of the very weak and stronger papers.

No.	Year	Uninked C.P. Folds	C.P. Tear	Uninked pH	Chemical Wood Fibers
634	1882	0	11.0	4.3	80% H.W., 20% S.W.
603	1882	0	14.8	4.6	60% H.W., 40% S.W.
627	1895	0	20.6	4.8	80% H.W., 20% S.W.
640	1884	1	10.2	4.4	70% H.W., 30% S.W.
636	1886	1	17.6	4.7	80% H.W., 20% S.W.
604	1886	1	25.0	4.8	55% H.W., 45% S.W.
635	1886	1	19.4	4.9	80% H.W., 20% S.W.
695	1883	1	13.2	4.9	60% H.W., 40% S.W.
705	1875	1	13.4	4.7	70% H.W., 30% S.W.
591	1879	1	14.2	4.4	60% H.W., 40% S.W.
643	1875	1	22.6	4.5	60% S.W., 40% H.W.
754	1895	1	16.8	4.1	60% H.W., 40% S.W.
611	1894	1	20.4	4.2	70% H.W., 30% S.W.
749	1893	1	10.2	4.3	80% H.W., 20% S.W.
626	1893	1	19.0	4.5	60% H.W., 40% S.W.
614	1893	1	17.8	4.6	85% H.W., 15% S.W.
613	1896	1	26.2	4.7	70% H.W., 30% S.W.
764	1885	2	13.0	4.5	60% H.W., 40% S.W.
766	1888	2	26.4	4.5	70% H.W., 30% S.W.
601	1884	2	32.4	4.5	50% H.W., 50% S.W.
698	1886	2	27.4	4.7	70% H.W., 30% S.W.
	Averages -	1	18.6	4.5	

Table 10
(continued)

No.	Year	Uninked C.P. Folds	C.P. Tear	Uninked pH	Chemical Wood Fibers
642	1879	3	31.8	4.6	90% S.W., 10% H.W.
686	1898	3	30.8	5.0	70% H.W., 30% S.W.
607	1881	3	15.2	4.7	50% H.W., 50% S.W.
697	1887	3	12.0	4.9	60% H.W., 40% S.W.
701	1872	4	17.8	4.5	70% H.W., 30% S.W.
691	1886	5	26.6	5.1	80% H.W., 20% S.W.
610	1883	5	39.6	4.6	60% S.W., 40% H.W.
628	1899	5	25.2	4.4	60% H.W., 40% S.W.
693	1887	7	14.8	5.2	60% H.W., 40% S.W.
633	1881	7	28.8	5.4	50% H.W., 50% S.W.
700	1889	8	15.2	4.5	50% H.W., 50% S.W.
639	1888	11	34.2	4.8	70% H.W., 30% S.W.
745	1899	16	37.2	5.1	60% H.W., 40% S.W.
761	1881	17	13.0	4.4	60% H.W., 40% S.W.
	Averages –	7	24.4	4.7	

Table 11

The number of folds (C.P. uninked), grams tear (C.P. inked), pH (uninked) and fiber analysis of 18 book papers 1870-1899 alum rosin sized and composed of 75% or more chemical wood fibers. Averages are included for the test values of the very weak and stronger papers.

No.	Year	Uninked C.P. Folds	C.P. Tear	Uninked pH	75% or more Chemical Wood Fibers
606	1887	0	22.4	4.6	60% H.W., 20% S.W., 20% S.
646	1872	1	14.8	4.3	40% S.W., 40% H.W., 20% S.
702	1872	1	17.2	4.9	65% H.W., 25% S., 10% S.W.
641	1875	2	44.4	4.5	60% H.W., 20% S.W., 20% S.
645	1872	2	14.4	4.5	50% S.W., 30% H.W., 20% S.
696	1887	2	19.0	4.6	60% H.W., 20% S.W., 20% G.W.
707	1879	2	20.8	4.8	60% S.W., 30% H.W., 10% S.
644	1870	2	10.8	4.9	60% S.W., 20% S., 20% H.W.
637	1886	2	21.8	4.9	60% H.W., 30% S.W., 10% S.
	Averages -	2	20.6	4.6	
647	1872	4	21.8	4.3	50% S.W., 30% H.W., 20% S.
708	1873	5	14.4	4.8	80% S.W., 10% S., 10% H.W.
605	1880	7	10.4	4.5	50% S.W., 30% H.W., 20% S.
602	1882	7	24.8	4.7	60% H.W., 20% S.W., 20% S.
694	1888	8	23.6	4.9	70% H.W., 20% S.W., 10% S.
	Averages -	6	19.0	4.6	
616	1890	9	20.0	5.6	45% H.W., 30% S.W., 25% S.
709	1876	11	14.0	4.6	70% S.W., 20% S., 10% H.W.
621	1893	12	20.2	5.7	60% H.W., 20% G.W., 20% S.W.
519	1892	15	58.4	5.8	50% S.W., 35% H.W., 15% G.W.
	Averages	12	28.2	5.1	

Table 12

The folding endurance, tear resistance, pH and fiber composition of nine samples, 1870-1892 containing groundwood.

Sample No.	Year	Folds Uninked C.P.	Folds Uninked W.P.	Tear C.P.	Tear W.P.	pH Uninked	% G.W.	% C.W.	% Rag
780	1886	0	0	8.4	10.0	3.8	60%	40% S.W.	-
796	1870	0	0	14.8	15.0	3.9	40%	-	60%
710	1870	0	0	17.6	14.4	3.9	80%	20% H. & S.W.	-
741	1892	1	0	18.2	20.8	4.1	40%	40% H.W. 20% S.W.	-
631	1887	1	1	6.6	4.8	3.8	70%	30% S.W.	-
696	1887	2	3	19.0	18.8	4.6	20%	60% H.W. 20% S.W.	-
621	1893	12	19	20.2	17.6	5.7	20%	60% H.W. 20% S.W.	-
519	1892	15	13	58.4	46.0	5.8	15%	50% S.W. 35% H.W.	-
771	1887	21	25	30.8	26.8	5.5	10%	60% H.W. 10% S.W.	20%

Table 13

The number of folds of the uninked and inked areas and the percent retention of 48 papers, 1800-1849, with 25 or more folds and a difference of ± pH 0.1 or less between inked and uninked areas.

Sample No.	No. C.P. Folds Uninked	No. C.P. Folds Inked	Percent Retention
989A	750	396	53
995E	323	262	81
527A	278	135	49
670A	211	222	105
524A	194	133	69
650E	180	83	46
997A	127	89	70
656E	116	101	87
987A	67	60	90
992A	62	45	73
983B	43	24	56
993E	33	22	67
991A	30	16	53
984B	30	29	97
978A	91	42	46
942B	88	48	55
980E	63	25	40
951A	33	14	42
950A	27	13	48
933A	195	103	53
926A	77	83	108
548E	76	24	32
927A	76	56	74
545A	58	35	60
924A	58	41	71
912E	52	28	54
904A	45	34	76
935A	39	32	82
546B	27	24	89

Table 13
(continued)

Sample No.	No. C.P. Folds		Percent Retention
	Uninked	Inked	
558A	1316	700	53
552A	321	177	55
560A	221	173	78
879E	77	69	90
864A	66	46	70
873A	42	26	62
881A	37	27	73
553A	28	19	64
737A	105	27	26
860B	76	111	146
732A	48	27	56
735A	43	22	51
859B	41	45	110
858E	34	36	106
827	81	56	69
833	41	44	107
726	36	26	72
805	28	28	100
703	36	22	61
		Average –	70

Table 14

The number of C.P. folds of the uninked and inked areas of 21 papers, 1800-1899, with 25 or more folds and a difference of ± pH 0.3 or more between the inked and uninked areas.

Sample No.	Difference in pH	No. C.P. Folds Uninked	No. C.P. Folds Inked	Percent Retention
585	1.0	99	43	43
801	0.4	137	66	48
666	0.3	34	16	47
663	0.5	73	32	44
846A	0.3	26	10	38
680A	0.9	45	20	47
736A	0.4	90	22	24
586A	0.3	92	33	36
843A	0.8	261	109	42
585A	1.4	295	126	43
906A	0.5	60	29	48
939A	0.5	132	51	39
913A	0.7	419	122	29
979A	0.5	27	10	37
966A	0.5	30	13	43
948A	0.4	40	16	40
977A	0.4	50	17	34
959A	0.3	51	22	43
973A	0.5	68	34	50
536A	0.5	70	19	27
964A	0.4	433	135	31
			Average –	40

Table 15

Percent cotton and linen, degree of fibrillation, C.P. folds and pH (cold ext.) of 75 samples for 1800-1849 arranged by decade.

1800-1809

Sample No.	Year	pH	No. Folds	Fibrillation	% Cotton	% Linen
658A	1800	4.2	5	medium	32	68
667B	1801	4.4	1	poor	9	91
659A	1802	4.1	11	medium	25	75
670A	1802	5.9	211	poor	10	90
648A	1803	4.8	13	"	25	75
527A	1803	5.0	278	good	59	41
938A	1804	4.6	6	"	35	65
525B	1804	5.5	243	"	46	54
528A	1805	5.3	11	poor	30	70
524A	1805	4.6	194	medium	30	70
996B	1806	4.5	11	poor	21	79
992A	1806	4.6	62	medium	37	63
993E	1807	5.6	33	poor	75	25
995E	1808	6.0	323	"	4	96
629A	1809	4.6	3	medium	7	93

Table 15 (continued)

1810-1819

Sample No.	Year	pH	No. Folds	Fibrillation	% Cotton	% Linen
965A	1810	4.6	4	poor	20	80
957B	1811	4.1	6	medium	17	83
537A	1811	5.2	154	good	21	79
941A	1812	4.3	3	"	24	76
967A	1813	4.4	6	poor	28	72
944A	1814	4.1	8	good	49	61
959A	1814	4.9	51	"	35	65
962A	1815	4.4	1	poor	18	82
950A	1816	4.6	27	good	38	62
536A	1816	4.7	70	medium	19	81
535A	1817	4.2	8	good	28	72
973A	1817	5.4	68	excellent	31	69
968A	1818	4.2	11	medium	50	50
964A	1818	6.5	433	excellent	30	70
942B	1819	4.7	88	good	38	62

Table 15 (continued)

1820-1829

Sample No.	Year	pH	No. Folds	Fibrillation	% Cotton	% Linen
911A	1820	4.2	2	poor	47	53
501A	1821	4.2	1	good	21	79
917A	1821	5.2	188	good	42	58
934A	1822	4.0	2	poor	28	72
927A	1822	5.7	76	excellent	25	75
919A	1823	4.6	9	poor	20	80
914A	1823	5.7	167	excellent	40	60
905A	1824	4.5	3	poor	17	83
930A	1825	4.1	5	poor	31	69
548E	1825	6.0	76	excellent	24	76
937A	1826	4.5	6	good	33	67
906A	1826	6.3	60	good	15	85
932A	1827	4.6	5	poor	27	73
928A	1828	4.2	4	poor	22	78
903A	1829	7.1	847	excellent	18	82

Table 15 (continued)

1830-1839

Sample No.	Year	pH	No. Folds	Fibrillation	% Cotton	% Linen
882A	1830	4.4	6	poor	19	81
552A	1830	5.3	321	good	38	62
893A	1831	4.7	7	poor	35	65
896A	1832	4.9	7	good	27	73
558A	1832	5.1	1316	excellent	45	55
888A	1833	8.2	117	good	20	80
884A	1834	7.8	66	medium	21	79
870A	1835	6.8	174	excellent	44	56
889A	1835	5.2	19	poor	35	65
866A	1836	7.0	1230	excellent	50	50
560A	1837	7.2	221	"	41	59
875A	1838	4.6	4	none	23	77
879E	1838	7.7	77	excellent	38	62
862A	1839	6.4	8	medium	20	80
895A	1839	7.8	21	"	28	72

Table 15 (continued)

1840-1849

Sample No.	Year	pH	No. Folds	Fibrillation	% Cotton	% Linen
852A	1840	6.0	9	medium	66	34
859B	1840	4.8	41	good	42	58
845A	1841	6.2	69	"	63	37
843A	1841	7.2	261	"	70	30
854A	1843	5.1	36	"	57	43
842A	1844	4.8	3	medium	79	21
568A	1844	5.8	95	"	87	13
841A	1845	4.4	10	"	65	35
679A	1845	7.8	82	good	63	37
505A	1846	4.2	0	poor	87	13
675A	1846	6.1	422	good	63	37
857A	1848	4.9	24	"	70	30
847A	1848	7.7	204	"	60	40
506B	1849	4.3	4	medium	48	52
565A	1849	8.6	295	good	54	46

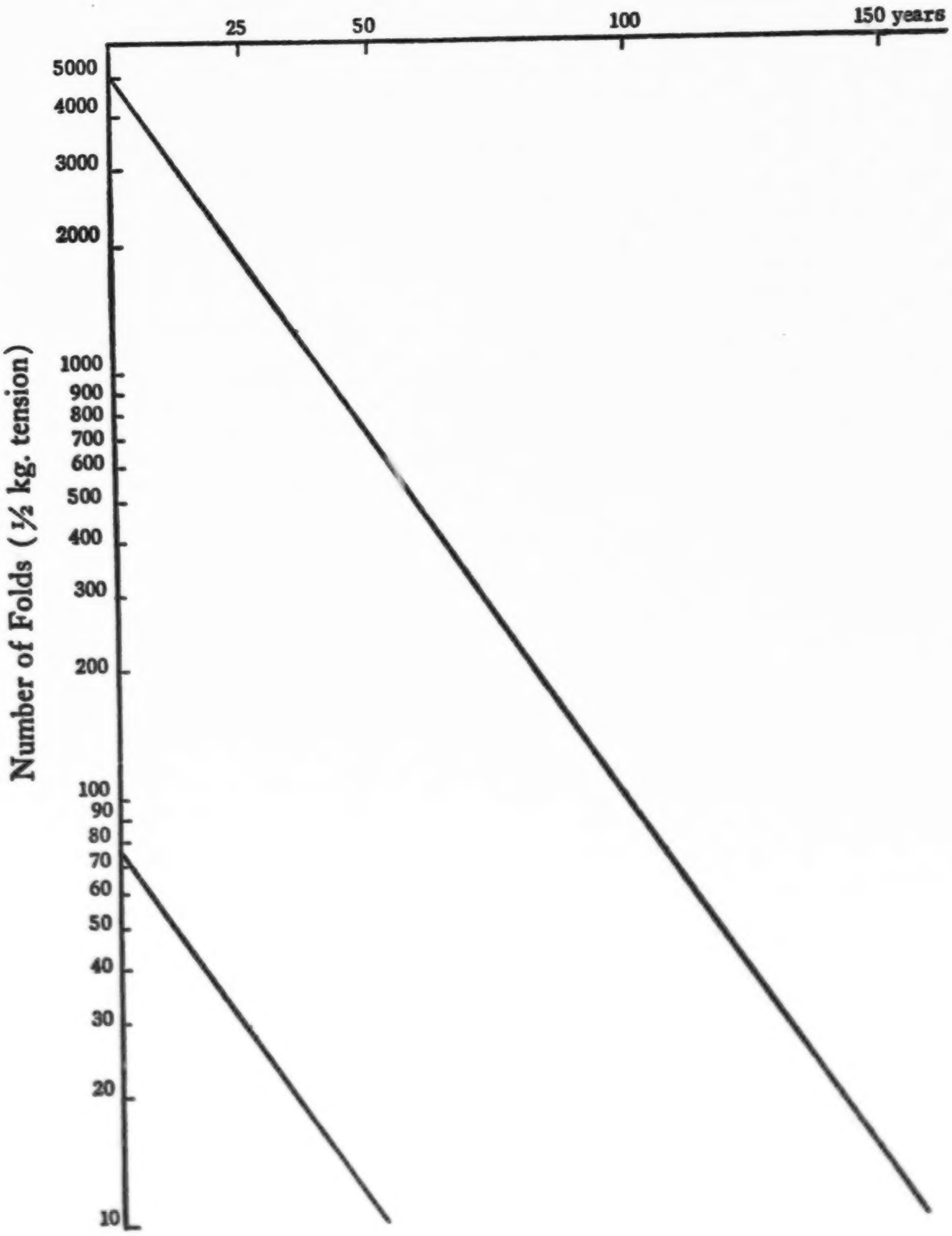
Table 16

Distribution by percent of 500 book papers from **Table 1**, into categories based on pH readings in uninked areas, by decade and chronological group.

	Percent					
Decade	**pH 4.0-4.5**	**4.6-5.1**	**5.2-5.9**	**6.0-6.9**	**7.0 +**	**Total**
1800-09	42	36	16	4	2	100
1810-19	34	52	12	2	0	100
1820-29	22	22	40	10	6	100
1830-39	6	22	24	20	28	100
1840-49	8	32	22	22	16	100
1800-1849	22	33	23	12	10	100
1850-59	14	42	20	6	18	100
1860-69	26	46	10	6	12	100
1850-1869	20	44	15	6	15	100
1870-79	52	40	8	0	0	100
1880-89	38	50	10	2	0	100
1890-99	44	34	18	2	2	100
1870-1899	45	41	12	1	1	100

FIGURE 1

Two types of book papers with identical pH and rates of deterioration, but because of difference in initial number of folds it requires 100 years longer for the strong paper to reach the low strength of 10 folds.



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